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~~AERORADIO~~ACTIVITY SURVEY AND AREAL GEOLOGY OF THE HANFORD PLANT AREA, WASHINGTON AND OREGON (ARMS-I)

Robert G. Schmidt

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AERORADIOACTIVITY SURVEY AND AREAL GEOLOGY OF THE HANFORD PLANT AREA, WASHINGTON AND OREGON (ARMS-I)

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ABSTRACT

A recent airborne gamma radioactivity survey in south-central Washington and north-central Oregon indicates a moderate range in the level of radioactivity and that the various levels are generally related to the geology of the region.

A survey of 9000 square miles near Pasco and Yakima, Wash., was made by the U. S. Geological Survey on behalf of the U. S. Atomic Energy Commission. Continuous radioactivity profiles were obtained with scintillation counting equipment at 500 ft above the ground on parallel north - south flight lines spaced 1 mile apart. Locally, the mountainous topography prevented operation of the aircraft on the planned flight lines, and in some of these areas a few substitute flights were possible along the valleys. A map of aeroradioactivity units was prepared from the profiles.

Bedrock in the Hanford Plant area consists largely of basalt, a variety of unconsolidated lake- and stream-deposited strata, and loess. The lake and stream deposits are generally associated with radioactivity of 200 to 600 cps (counts per second), the basalt with radioactivity of 400 to 800 cps, and the loess with radioactivity of 500 to 800 cps. Changes in radioactivity level occur at the contact between geologic units at only a few places, however, because of the widespread redistribution of surficial material by wind action in the area.

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1. INTRODUCTION

1.1 Location of Area

An airborne radioactivity survey of the Hanford Plant area, Washington and Oregon, was made by the U. S. Geological Survey on behalf of the Division of Biology and Medicine, U. S. Atomic Energy Commission, as part of the Aerial Radiological Measurement Survey (ARMS-I) program. The area studied is a square 100 miles on a side, centered on the Hanford Plant nuclear facility, in which about 9000 square miles were surveyed (Fig. 1).

1.2 Purpose of Survey

The ARMS-I Hanford survey is part of a nationwide program to obtain data on the existing gamma radioactivity for areas in and adjacent to nuclear facilities. These data provide information that can be used to detect any future variations in radioactivity which might result from nuclear testing, reactor or other Atomic Energy Commission operations, or radiation accidents.

1.3 Airborne Survey Procedure

The survey was flown between June 24 and July 23, 1959, under the direction of J. L. Meuschke and P. W. Philbin, and made with scintillation-detection equipment installed in a twin-engine aircraft. Parallel north - south flight lines at 1-mile intervals were flown approximately 500 ft above the ground at an average air speed of 150 miles per hour. Parts of many flight lines could not be flown because of rugged topography. In the western part of the area, north and east

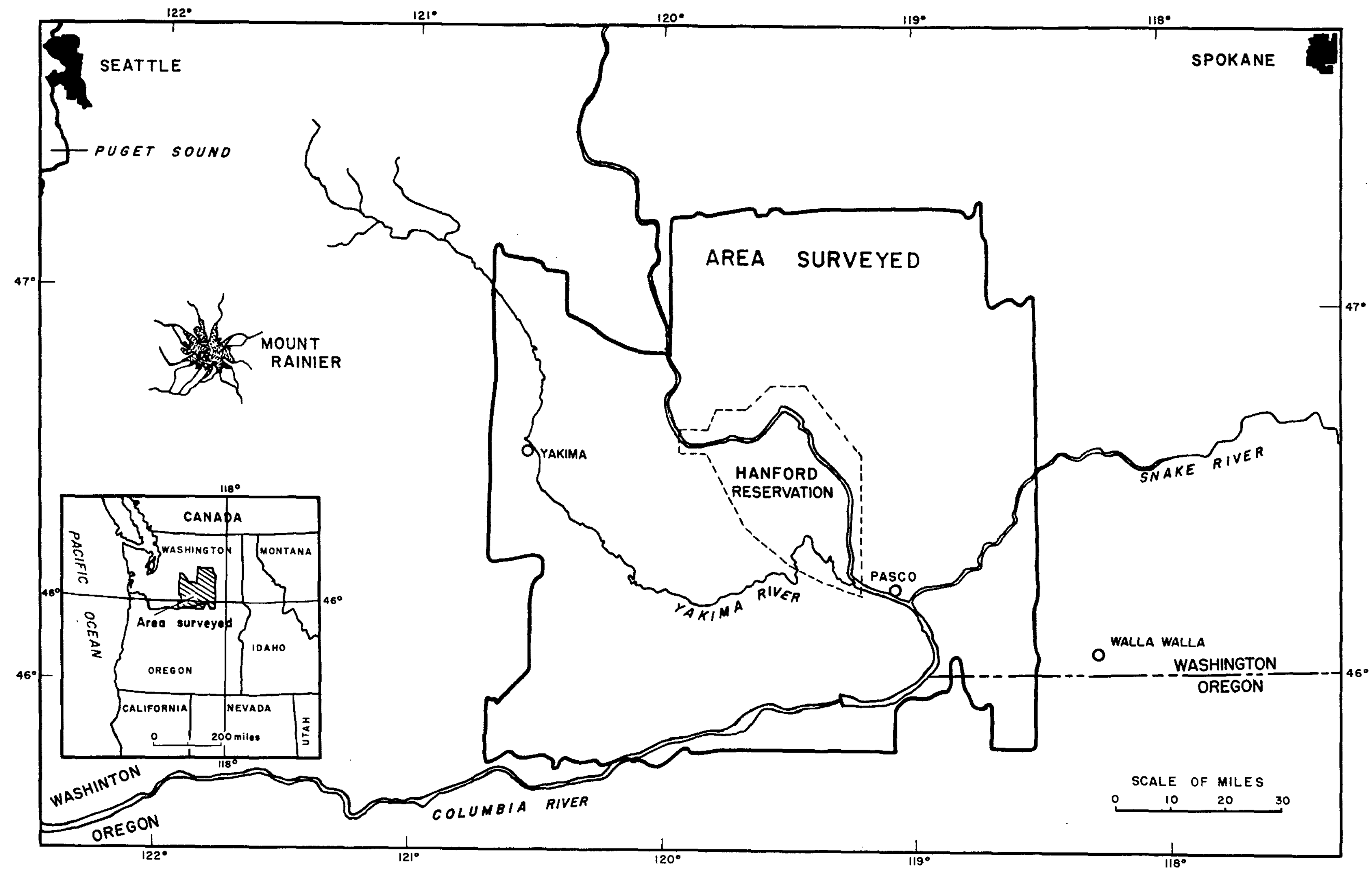


Fig. 1—Location of the Hanford Plant area.

of Yakima, flights were made along roads in the valleys because normal traverse lines could not be flown at the required altitude. Aerial photographs and topographic maps were used for pilot guidance. The flight path of the aircraft was recorded by a gyrostabilized continuous-strip-film camera and distance from the ground was measured by a continuously recording radar altimeter. Fiducial markings providing a common reference for the radioactivity and altimeter data and the camera film were made with an electromechanical edgemark system operated by the flight observer when the aircraft passed over recognizable features on the ground.

1.4 Scintillation Detection Equipment

The gamma-radioactivity detection equipment used by the Geological Survey was designed by the Health Physics Division of the Oak Ridge National Laboratory and has been described in detail by Davis and Reinhardt[1]. They describe the sensitivity of the equipment in several ways, one being (p. 717) " . . . With a microgram of radium at one foot from the crystals, the counting rate is roughly 2000 cps (counts per second)." Kermit Larsen of the University of California at Los Angeles (written communication) determined in 1958 that a count rate of approximately 77,000 cps measured at 500 ft above the ground by the Geological Survey equipment is equivalent to 1 mr/hr measured at 3 ft above the ground. This comparison was made over an infinite fallout source, the source being of infinite dimension insofar as the area of response of the airborne equipment is concerned.

A diagram of the equipment is shown in Fig. 2. The detecting element consists of six thallium-activated sodium iodide crystals, 4 in. in diameter and 2 in. thick, and six photomultiplier tubes connected in parallel. The signal from the detecting element is fed through amplification stages to a pulse-height discriminator which is usually set to accept only pulses originating from gamma radioactivity with energies greater than 50 kev (thousand electron volts). The signal is then fed to two rate meters. One rate meter feeds a circuit that records total count on a graphic milliammeter. The signal from the other rate meter is recorded by a circuit that includes a variable resistance which is controlled by the radar altimeter servomechanism, which approximately compensates the data for deviations from the nominal 500 ft surveying altitude. The cosmic background is removed before the data are compensated. The topography is locally very rough in the Hanford Plant area and in several places the roughness exceeds that which can be satisfactorily handled by the compensator system. This usually occurred in narrow steep-walled canyons where the cone of response of the radar altimeter was limited to the canyon bottom, but the response area of the radioactivity detection system included the canyon walls. The compensated radioactivity in such places was consequently higher than normal.

The crystals are shielded on the sides by $\frac{1}{2}$ in. of lead, which negates any influence of the radium-dial instruments in the aircraft. The effective area of response at an elevation of 500 ft is approximately 1000 ft in diameter, and the radioactivity recorded is an average of the radioactivity received from within the area. Theoreti-

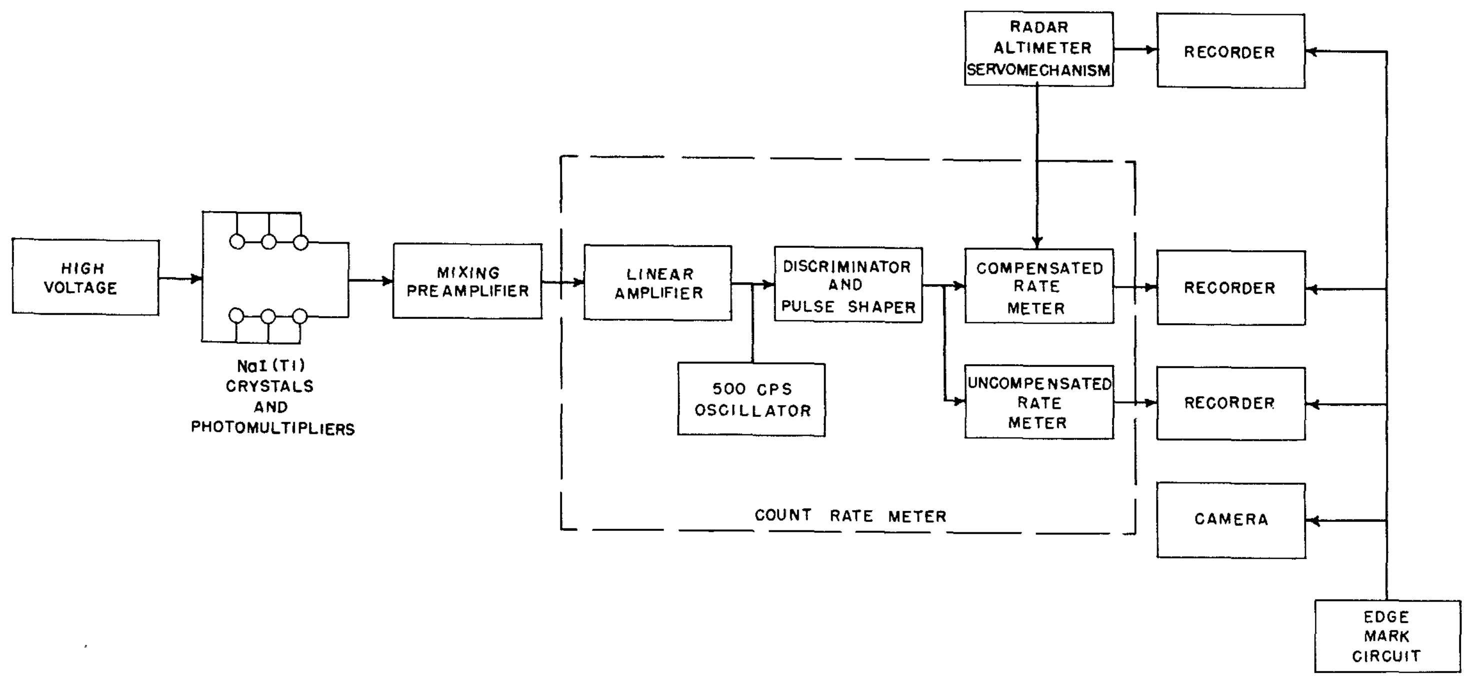


Fig. 2—Diagram of airborne radioactivity survey equipment.

cal aspects of the area of response and other considerations are discussed by Sakakura[2], Moxham[3], and Gregory[4].

The gamma-ray flux at 2000 ft above the ground, which comes from cosmic radioactivity and to a much lesser extent from radionuclides originating from the ground, is measured twice each day while surveying. This quantity is called the cosmic background at 2000 ft, and is removed from the compensated circuit. The cosmic background measured at 2000 ft during the Hanford survey ranged from 320 to 450 cps. A portion of a regular flight line, called a test line, is flown at the normal survey altitude at the beginning and the end of each day's surveying. An approximation of the amount of diurnal variation of atmospheric radionuclides can be obtained by comparing these data.

1.5 Theoretical Considerations

The gamma-ray flux at 500 ft above the ground has three principal sources: cosmic radioactivity, radionuclides in the air (mostly radon daughter products), and radionuclides in the surficial layer of the ground. The contribution of the cosmic component at a particular time can be determined. However, the component due to radionuclides in the air at 500 ft above the ground cannot be separated from the ground component. It is affected by meteorological conditions, and a 10-fold change in radon concentration is not unusual under conditions of extreme temperature inversion. Values for diurnal variation cannot be obtained from test-line data flown at the beginning and the end of each day since 450 to 600 traverse miles are flown during an average flight of 4 to 6 hrs. The air component, if inversion conditions are avoided, may be considered to be fairly uniform on a given day in a particular area.

The ground component comes from the approximate upper few inches of the ground, and consequently the influence of a thin surficial veneer of wind-transported material may be relatively high. The ground component consists of gamma rays from natural radionuclides (principally K^{40} and members of the uranium and thorium radioactive decay series) and radioactive fission products in fallout. Locally, the amount of fallout must be small, since the lowest total radioactivity measured is 160 cps. Gustafson, Marinelli, and Brar[5] concluded from a study of the radioactivity of soil from Lemont, Ill., that in the spring of 1957 the activity due to fallout was less then one-tenth the total gamma activity of the soil. Although the Plumbbob tests in 1957 produced considerable fallout, data from periodic resurveys of test lines in Virginia, Texas, and New Mexico by the Geological Survey (J. L. Meuschke, personal communication) indicate that fallout probably accounted for much less than 100 cps of the background in those areas. The distribution of fallout in the Hanford Plant area is assumed to be uniform.

Locally, in and near the Hanford Plant, the contribution of radioactivity resulting from individual plant activities interfered with measurements to the extent that natural radioactivity could only be inferred from the geologic units present. The radioactivity measured in the Plant area is discussed in Sec. 4.

The present distribution and concentration of natural radionuclides in the surficial material are determined by the original con-

tent and form of the radioactive material in the parent rock and by changes brought about by geologic and soil-forming processes. An important consideration in studying the radioactivity of a soil is whether it is a residual soil derived from the rock beneath it, or a transported soil, which may be derived from rocks that are entirely different from those on which the soil rests. Although complete studies of the distribution of natural radionuclides in the various soil and rock components of the surficial layer have not been made, information concerning individual components is available. Radioactive heavy minerals, such as monazite, a rare-earth phosphate containing as much as 30 per cent thorium, and zircon, a zirconium silicate containing as much as 1 per cent uranium, are known to be present in small quantities in many types of rocks and soils.

The concentration of these minerals at the surface of a residual soil may be greater or less than their concentration in the parent rock, depending upon the interplay of the various soil-forming processes, but generally the radioactivity level measured approximates that of the bedrock. Uranium and thorium, and their daughter products, are commonly present in rock and soil in amounts ranging from traces to several parts per million. The content of all potassium isotopes of the surficial layer may be as much as several per cent, of which K^{40}, the only radioactive potassium isotope, is a minute part. Rough averages for the amounts of these elements in common rocks in parts per million are given in Table 1 (adapted from Turekian and Wedepohl[6]).

Table 1 — APPROXIMATE AMOUNTS OF URANIUM, THORIUM, AND K^{40}

IN COMMON ROCKS

Rock	Uranium, ppm	Thorium, ppm	K^{40}, ppm
Granitic rock	3	8.5-17	3-5
Basaltic rock	1	4	1
Sandstone	0.45	1.7	1.3
Shale	3.7	12	3
Carbonate rock	2.2	1.7	0.3

1.6 Ground Survey

A ground reconnaissance study was made between July 19 and Aug. 1, 1960, to determine the relations between the air and the ground components of gamma radioactivity. Provisional geologic maps prepared from soils-survey maps were field checked, and soils and rocks were described and sampled.

The natural gamma radioactivity recorded at 500 ft above the ground ranged from 160 to 900 or 1000 cps, and is the general level to be expected over the types of rocks and soils exposed in the area. The ground study disclosed that the radioactivity is generally only roughly related to the geology but locally excellent correlation exists. The prevalence of thin and thick eolian deposits over a large part of the area seriously complicates interpretation. The natural radioactivity on the ground was found to range from 0.01 to 0.04 mr/hr.

1.7 Compilation of Aeroradioactivity Data

The altitude-compensated radioactivity profiles were used in the preparation of the map "Aeroradioactivity of the Hanford Plant area, Washington and Oregon" (in pocket). This map is also published in the Geological Survey's Geophysical Investigations Map Series[7].

Flight-line locations from the strip film obtained during the course of surveying were plotted on the compilation base maps (scale, 1 in. equals 1 mile). Radioactivity profiles from adjacent flight lines were examined and changes or breaks in the level of the radioactivity record were correlated from line to line. The changes on the radioactivity record are indicated on the map (in pocket) by solid or dashed lines, dependent on the degree of correlation. The difference between the lines is a matter of degree, the solid lines denoting distinct changes in level of radioactivity, the dashed lines denoting relatively less distinct, generally transitional changes. Areas between the lines of change were assigned general ranges of radioactivity levels by scanning the records obtained over the specific areas. The lines of change and the radioactivity levels were plotted along flight lines on transparent overlays of the compilation base maps. The overlays were reduced to a scale of 1 in. equals about 4 miles (1:250,000) and the data plotted on sheets of the Army Map Service, Corps of Engineers 1:250,000-scale topographic map series. The final map (in pocket) was thus derived, showing radioactivity levels and lines of change and major cultural and drainage features. The various patterns of green indicate generalized levels of radioactivity. Fig. 3 is a reduced and generalized version of the 1:250,000 map designed for easy comparison with the geologic map (Fig. 4) at the same scale.

2. GENERAL GEOLOGY

Bedrock in the Hanford Plant area consists of sedimentary and volcanic rocks of Cretaceous to Recent age, but rocks older than Miocene occupy only a very small part of the area. Much of the area is extensively mantled by thin to thick coverings of Pleistocene and Recent eolian deposits, but these are separately mapped only where they are at least several ft thick. Because most of the gamma radioactivity measured at 500 ft comes from the top few inches of the ground, the widespread windblown material tends to mask the radioactivity of the bedrock.

The geology of the Hanford Plant area is shown on Fig. 4. Most of the area is underlain by Yakima Basalt. The basalt is succeeded by various Pliocene to Recent deposits of gravel, sand, silt, tuff, and clay, and glacial outwash of gravel, sand, and silt. Highland

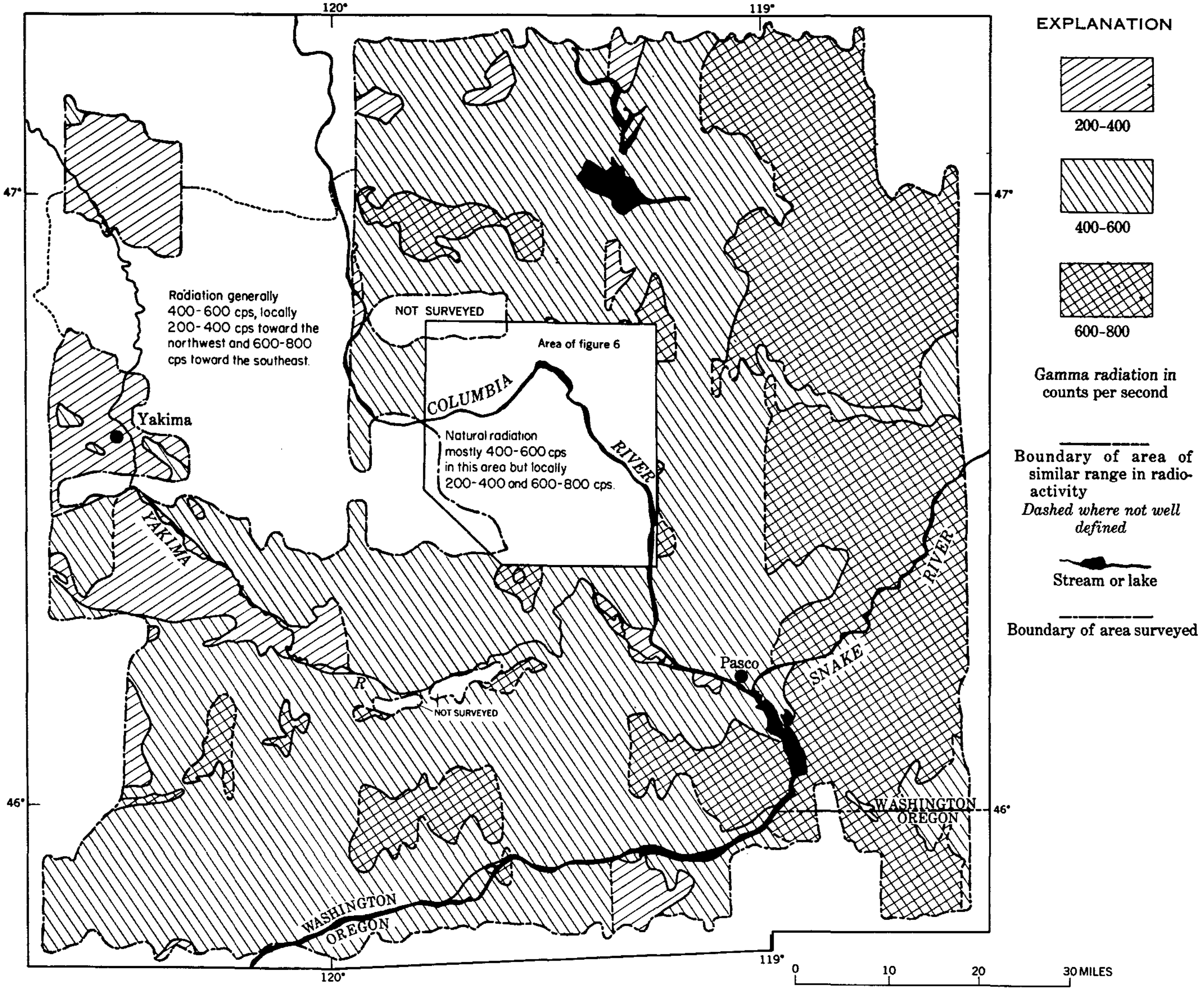


Fig. 3—Generalized aeroradioactivity map of the Hanford Plant area, Washington and Oregon.

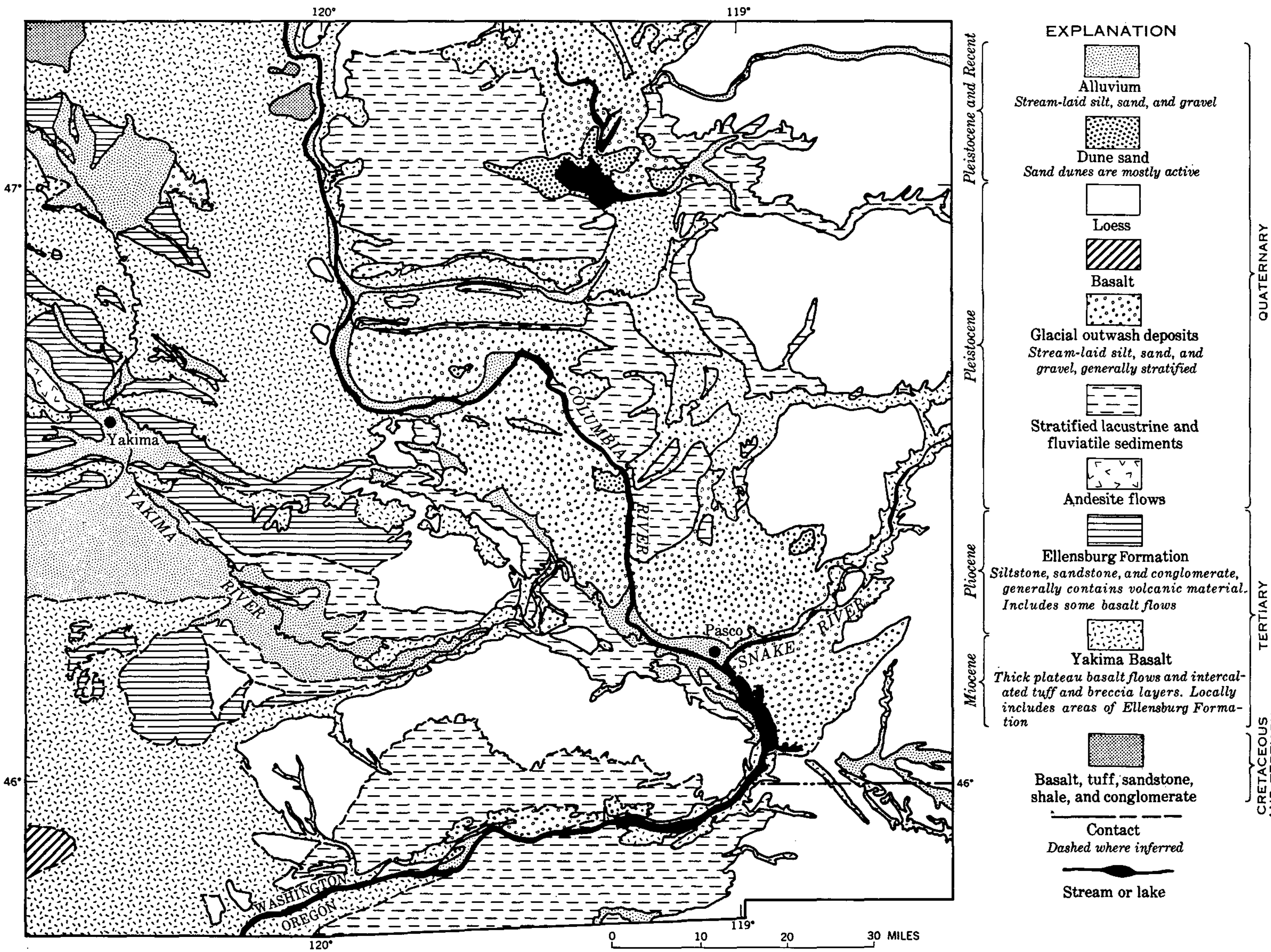


Fig. 4—Generalized geologic map of the Hanford Plant area, Washington and Oregon.

areas on the Horse Heaven Hills and in the northeastern and eastern parts of the area are covered by a few inches to more than 200 ft of fine wind-deposited silt or loess. There are local areas of alluvium, talus, and landslide materials. Northwest of Yakima along the Naches River, is a small area of Pleistocene lava flows, the Tieton Andesite, and in the southwest part of the area are some Pleistocene basalt flows.

In the eastern half of the Hanford Plant area, the rocks are nearly flat-lying or dip gently; in the western half the rocks are folded in a series of prominent ridge-forming anticlines and basinal synclines that trend from east - west to N 30°W[8].

The area north and east of the Hanford Plant reservation includes a part of the scablands, a remarkable network of anastamosing glacial river courses[9]. In typical scablands the overlying sediments have been stripped from the basalt flows and locally the basalts are deeply channeled.

3. STRATIGRAPHIC SUCCESSION AND RELATED AERORADIOACTIVITY

The Yakima Basalt and intercalated tuffs and sedimentary layers of the Columbia Plateau occur at the surface or are buried by younger strata in almost all of the area surveyed. The maximum thickness of the basalt is not known but it exceeds 10,600 ft on Rattlesnake Ridge, where some of the youngest basalt layers have been removed by erosion (R. E. Brown, General Electric Co., oral communication, 1960).

A few small areas of Cretaceous and Tertiary rocks older than the Yakima Basalt occur in the northwest part of the area but none occur in the area surveyed in detail. The rocks include, shale, sandstone, conglomerate, tuff, and older basalt.

Most of the Yakima Basalt may be Miocene, but some of the youngest flows are Pliocene[8]. The Yakima Basalt flows are generally[8] monotonously similar in composition and appearance. An average flow is 75 to 200 ft thick, scoriaceous to rubbly at the top, generally nonporphyritic, and has two or three tiers of columnar or other types of jointing. Intercalated sedimentary layers are more abundant near the top of the basalt, and the basalt flows are believed to have given way to sedimentary strata (the Ellensburg Formation) earlier in the western part of the area. Micaceous silt, sandstone, and clay, and some conglomerate, diatomite, and residual soils occur as interbeds in the basalts. Petrified wood is locally abundant, as in Ginkgo Petrified Forest State Park.

The areas where basalt outcrops were abundant gave an average of 350 to 600 cps. The areas shown as Yakima Basalt in Fig. 4 include the Wenas Basalt Member of the Yakima Basalt, and also basalt layers in the Ellensburg Formation, such as the Selah Butte and Elephant Mountain flows of Waters[8]. Field reconnaissance and examination of aerial photographs indicated that basalt is exposed more extensively in the southwest part of the area than was previously believed, although this basalt is associated with thick sedimentary interbeds that may be correlated with the Ellensburg Formation.

The Ellensburg Formation overlies the Yakima Basalt at many places in the western half of the area. The Ellensburg pinches east-

ward as the lower strata interfinger with the basalt in that direction. The formation is early Pliocene in age.

The Ellensburg Formation is largely composed of coarse and fine andesitic debris derived from andesitic volcanoes to the west and was deposited as compound fans in the gradually forming synclinal basins. Minor angular unconformities are followed by thin layers of basalt gravels derived from the adjacent uplifted ridges. At least three basalt flows are interlayered in the lower part of the Ellensburg Formation. These are similar to the Yakima Basalt[8].

The radioactivity of the Ellensburg Formation is relatively low, 300 to 400 cps. Radioactivity levels as high as 1000 cps are associated with several narrow canyons that probably expose Ellensburg in the southwestern part of the area, but a field check of Spring Canyon and Rock Creek revealed no variation in radioactivity from that of the surrounding Yakima Basalt. The high radioactivity recorded by the airborne survey over the canyons is almost certainly the result of overcorrection by the compensation circuit rather than high radioactivity from the Ellensburg Formation. The uncompensated circuit indicated less radioactivity over the canyons than over the adjacent basalt.

The full extent of the Ellensburg Formation in the Hanford Plant area is not known. It is provisionally shown to be much more extensive on Fig. 4 than previously mapped, particularly in the large area south of Yakima about half way between Yakima and the Columbia River, and in the belt near Yakima now shown to extend southeastward toward Pasco for more than 35 miles. These areas were outlined by study of aerial photographs, on which the Ellensburg and its intercalated flows have a characteristic appearance.

The Tieton Andesite of Pleistocene age occurs in a prominent lobe between the Naches River and Cowiche Creek northwest of Yakima. The andesite is moderately radioactive, 440 to 570 cps, and an area at the southeast end of the exposure, about 2 miles wide and 3 miles long, is distinctly more radioactive than the surrounding area (Fig. 5). The edges of part of the area of higher radioactivity correspond closely to the edges of the andesite.

Stratified lake and stream deposits of Pleistocene age are widespread in the district and include a great variety of materials. The best known unit is probably the Ringold Formation; others are the Touchet Beds of Flint[10], the lake beds of Quincy Valley[11], and others not specifically described.

The stratified lake and stream deposits are very extensive in the Hanford Plant area (Fig. 4). They consist of only slightly deformed clay, silt, and sand, and gravel. Locally they include large amounts of reworked loess. Unlike the Ellensburg Formation, little or no pyroclastic material occurs in these strata. Where the Ellensburg is not particularly tuffaceous and is nearly flatlying, it may be very difficult to distinguish the strata.

The widespread extension of these beds in the Yakima River valley, based on soils-survey maps and study of aerial photographs, is very speculative. The even larger extension on both sides of the Columbia River where it forms the Washington - Oregon boundary is mostly outlined by interpretation of soils-survey maps supplemented by aerial photographs. The stratified beds were confirmed in the field in many places on the Washington side and in a few on the

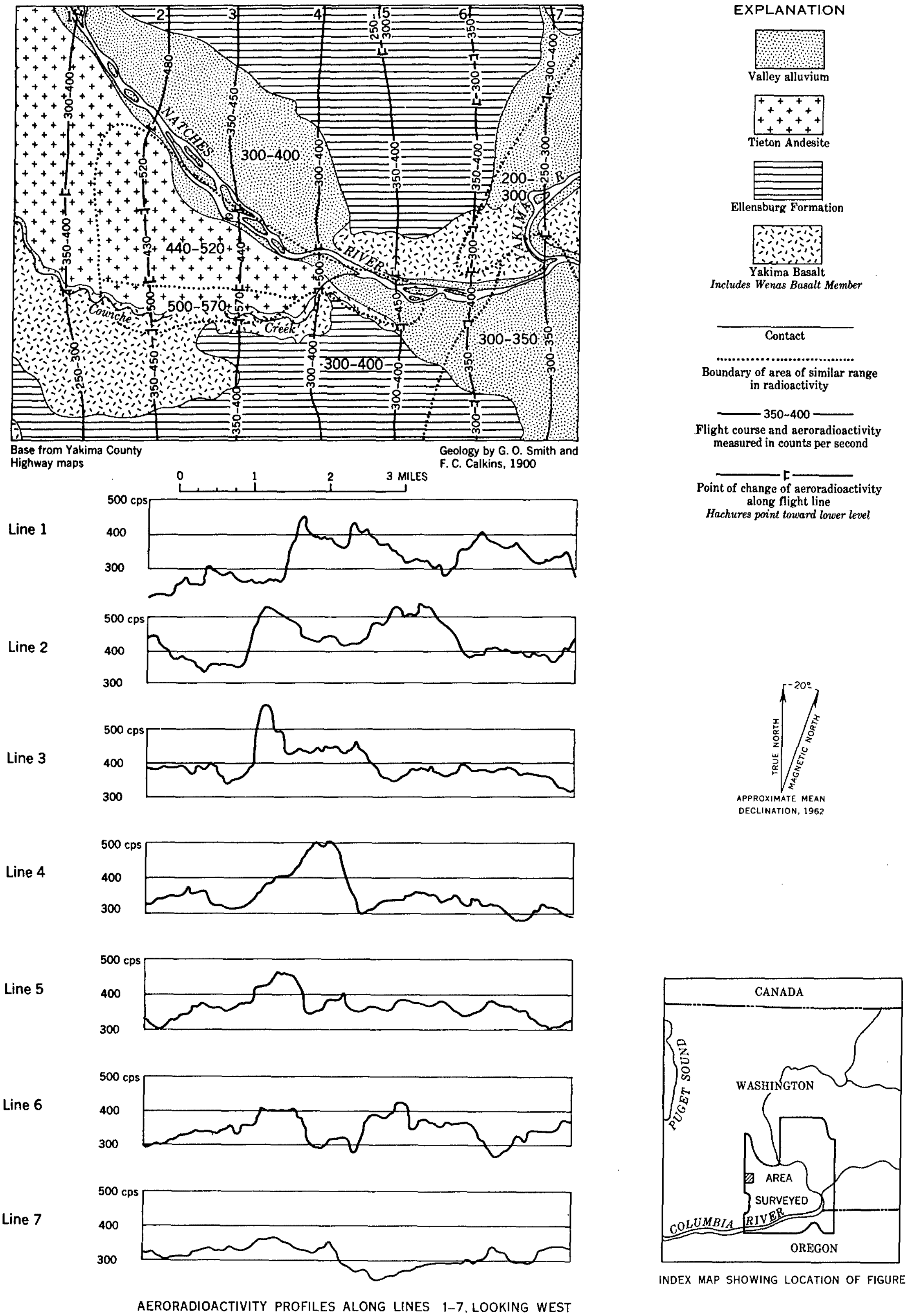


Fig. 5—Detailed aeroradioactivity and geology of an area near Yakima, Washington.

Oregon side. Note the similarity of this area of stratified beds to Allison's outline of glacial flooding[12]. In the Frenchman Hills - Quincy Valley area, soils-survey maps were given somewhat more weight than geologic maps in regard to the distribution of loess, and consequently the entire crest of Frenchman Hills is here shown as stratified deposits rather than loess, the surface doubtless modified by the wind. This was not checked in the field.

The radioactivity measured over the stratified lake and stream beds is moderate, generally 400 to 600 cps and perhaps locally as much as 750 cps. The higher radioactivity measured over the Frenchman Hills (600 to 800 cps) suggests that the hills are covered by loess and does not support the interpretation made here that they are composed of stratified deposits.

All the Hanford area was outside the limits of continental glaciation, but glaciofluvial deposits of clay, sand, gravel, and boulders are locally abundant, especially along the Columbia River and in the scablands. The glacial deposits have a general associated radioactivity of 300 to 550 cps. In a large area south of the Snake River, the radioactivity level over outwash is 560 to 700 cps, but perhaps this is due to a thin veneer of windblown silt for which this radioactivity level is about right.

Ice-rafted erratics, some many feet in diameter, are scattered over wide areas, but are limited to places below the limit of highest glacial flood waters, about 1100 ft elevation in the Pasco Basin.

Quaternary basaltic volcanic rocks are abundant outside the southwest corner of the Hanford Plant area, north of the Columbia River, and extend into the mapped area in one place. The rocks are chiefly basalt flows, but cones in the area suggest that pyroclastic material may also be present. The surface textural patterns of individual flows are clear in aerial photographs and the outline of the area of flows was roughly sketched from aerial photographs.

Loess occurs widely over the Hanford area and includes the Palouse Formation described by Bryan[13]. The soil is generally homogeneous in composition, but there are some notable regional and local differences--described chiefly by soils surveys. The loess ranges from a thin mantle to a deposit more than 200 ft thick[14]. Much of the loess is of Pleistocene age, and the bulk is believed to be pre-Wisconsin[13]. Some of the silt, however, is younger, and a limited amount of deposition of similar material continues at the present. The silt is believed to have been carried by wind from the southwest, perhaps derived in part by wind erosion of stratified lake and stream deposits, such as the Ringold Formation[15]. Little loess seems to occur west of the large areas where such stratified deposits are shown on Fig. 4.

The loess is the most radioactive unit in the area, generally associated with radioactivity of 500 to 750 cps in the eastern part of the area where higher radioactivity correlates rather well with the areal distribution of the loess (Figs. 3 and 4). The loess on the Horse Heaven Hills is associated with similar high radioactivity toward the east but with levels of 350 to 650 cps farther west.

Patches of active sand dunes are present in many places in the area though only six are large enough to show on Fig. 4. In addition, many wind-modified surfaces on glacial outwash and stratified deposits are arrested sand dunes; such areas are not differentiated on the

geologic map. Radioactivity of 380 to 660 cps was found to be associated with the various dune areas.

Recent alluvium covers the floors of many of the valleys. The alluvium in the Yakima and Moxee Valleys is associated with low radioactivity levels, from 160 to 500 or 550 cps.

4. DETAILED AERORADIOACTIVITY OF PART OF THE HANFORD PLANT RESERVATION

Fig. 6 shows the detailed gamma radioactivity measured in, and adjacent to, the Hanford Plant nuclear facility. Natural radioactivity, as shown on both Figs. 3 and 6 and on the 1:250,000 aeroradioactivity map (in pocket), is inferred (see Sec. 1.4) mostly to be 400 to 600 cps, and occasionally 200 to 400 cps and 600 to 800 cps. The extent of Fig. 6 is shown on Fig. 3.

Slightly higher readings within the plant area are indicative of known fixed sources of radioactivity. The higher readings north of the river are the result of rapidly decaying (very short half life) isotope mixtures in the form of invisible variable clouds that are at harmless levels for individuals on the ground within the plant area or in the immediate plant environs. These clouds are released from the reactor effluent retention basins in directions dependent on meteorological conditions.

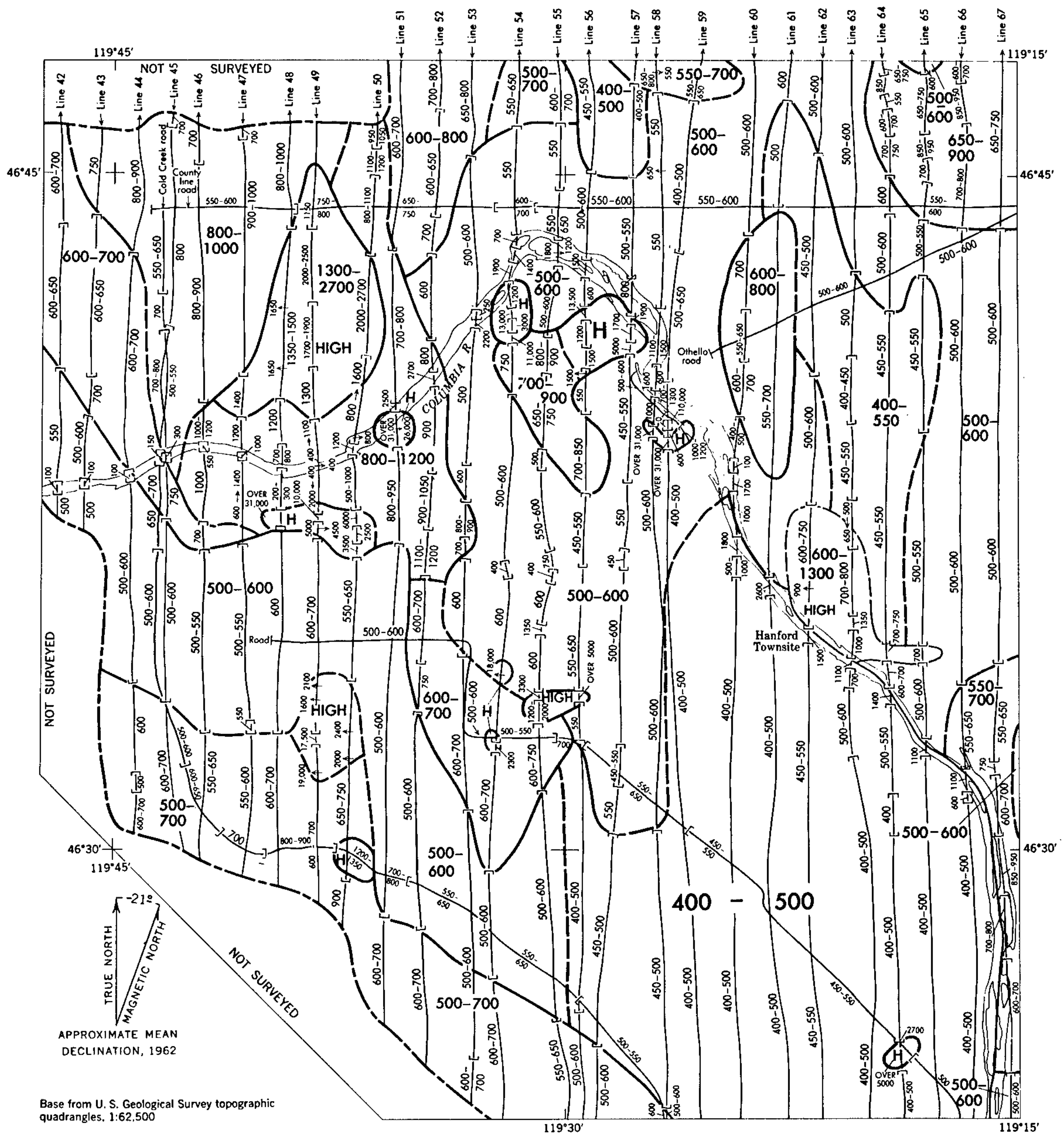
The results of a special airborne traverse along the Columbia River are stated in the text on the 1:250,000 aeroradioactivity map (in pocket).

The above described levels of radioactivity result from normal atomic energy operations at the Hanford Plant facility. Also, the Geological Survey airborne radioactivity equipment (instrumentation) is extremely sensitive to small changes in radiation levels.

Information on radioactivity levels in the environs and outside the plant boundaries of Atomic Energy Commission and contractor installations is given in special periodic reports from each installation. These reports are published in the U. S. Public Health Service series titled "RADIOLOGICAL HEALTH DATA", issued monthly and available from the Government Printing Office, Washington, D. C.

5. STRUCTURAL GEOLOGY

The strata in the eastern part of the Hanford Plant area are nearly flat lying and relatively structureless; but, generally west of a north - south line passing through Pasco, a system of folds has formed from late Miocene or early Pliocene through the Pleistocene, and differential movement of bench marks suggests that folding is still in progress (R. E. Brown, oral communication). The folds trend east-west to N30°W, and the dips of strata are generally steeper on the north side of the anticlines; the strata are nearly vertical or



EXPLANATION

700–900
General level of aeroradioactivity measured in counts per second

Boundary of area of similar range in radioactivity
Dashed where inferred

HIGH or H
Aeroradioactivity high, believed due to activities of Hanford Plant

500-600
Flight course and aeroradioactivity measured

Point of change in aeroradioactivity along flight course
Hachures point toward lower aeroradioactivity

650
400
Location of narrow aeroradioactivity high or low along flight course

←Line 56
Direction of flight course and line number

Boundary of area surveyed

1 0 1 2 3 4 5 MILES

Fig. 6—Detailed aeroradioactivity of part of the Hanford Plant reservation.

slightly overturned on one side of many of the folds. Folding has progressed faster than erosion and the anticlines form prominent ridges; the synclines are valleys that contain sediments derived by erosion of adjacent ridge tops. There is probably some folding trending N45°W near the Washington - Oregon border in the southeast.

Few faults have been mapped in the Hanford Plant area, partly because little detailed mapping has been done. Only minor faults were found in the Yakima East Quadrangle[8].

6. SCABLANDS

The scablands are elongate river courses, on bare or nearly bare rock where the loess and other cover have been vigorously stripped away. The channels divide and unite in an anastamosing pattern. Many channels have canyons in them. The bounding slopes of loess may be strikingly steep.

The scablands were formed by a period of exceedingly vigorous stream erosion and gravel deposition near the end of Pleistocene glaciation. The amount of water capable of performing the erosion and the source of such a flood have been much debated subjects[9].

7. GENERAL SUMMARY

The radioactivity reasonably attributable to natural sources in the Hanford Plant area ranged from 160 to 900 cps. A rough correlation was found between the aeroradioactivity level and the type of rock or sediment occurring at the surface. Radioactivity ranges generally associated with the commonest geologic units were: Yakima Basalt, 350 to 600 cps; Ellensburg Formation, 300 to 400 cps; stratified lake and stream deposits, 400 to 600 cps; glacial outwash, 300 to 700 cps; wind-deposited silt, 350 to 750 cps; and Recent alluvium, 160 to 500 cps.

The results of the Hanford airborne radioactivity survey indicate that the Hanford Plant area is one of low to moderate natural radioactivity and that the radioactivity shows little variation over relatively large expanses. The general correlation of aeroradioactivity and geologic units will probably be of local use in the Hanford area, but the correlation is not so good as that in some other places, e. g., in the Piedmont Province of southeastern United States[16,17].

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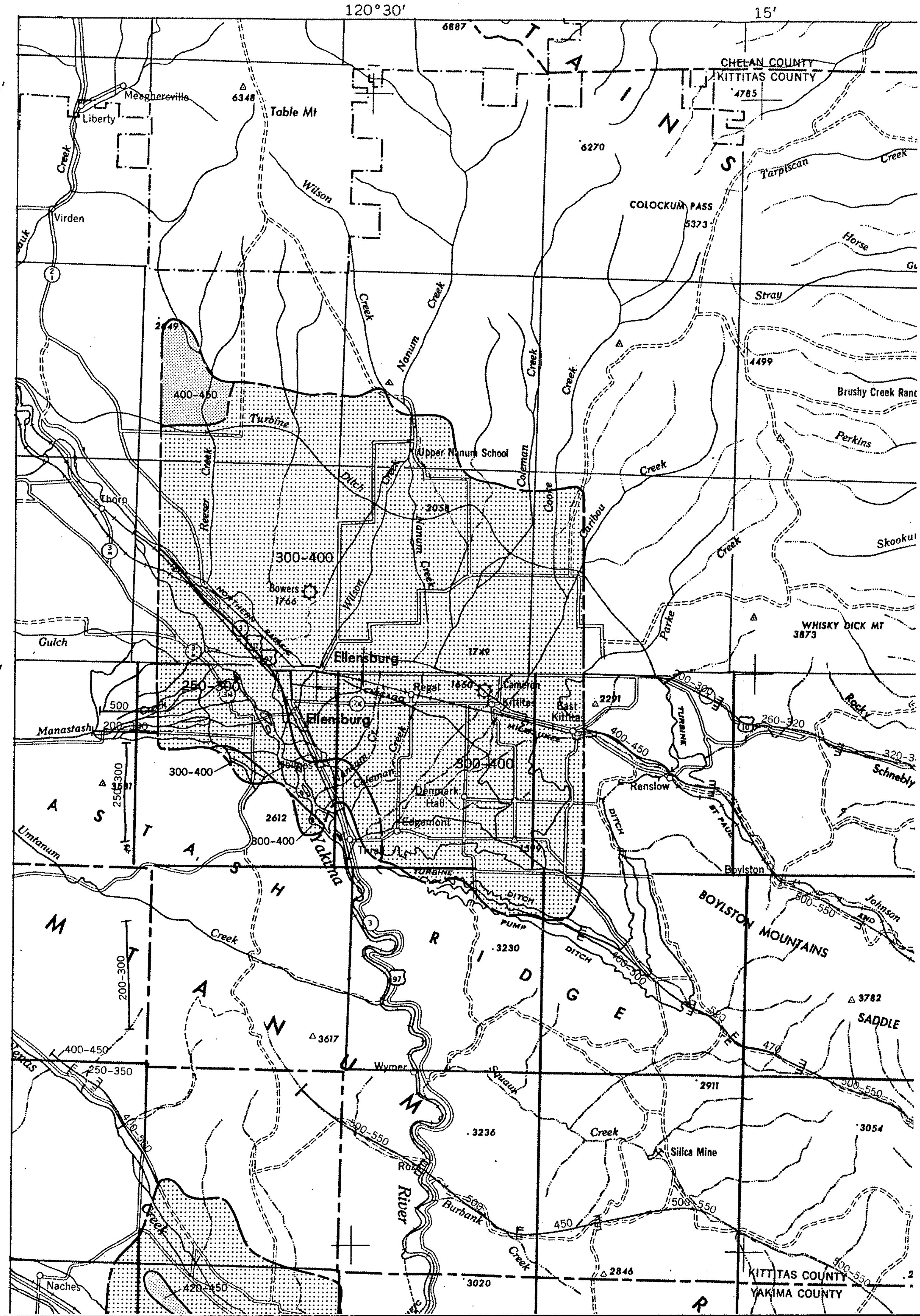
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



2

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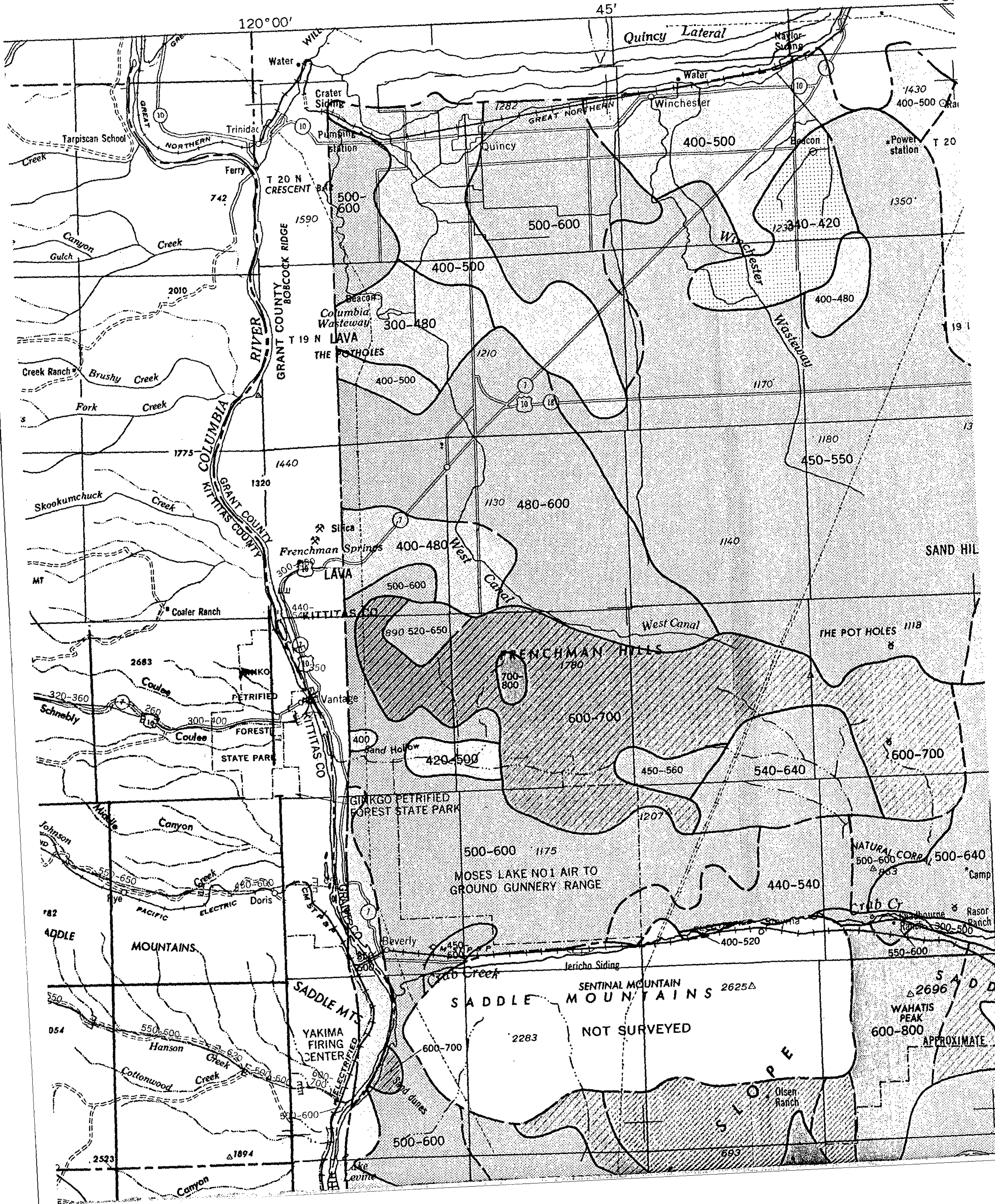

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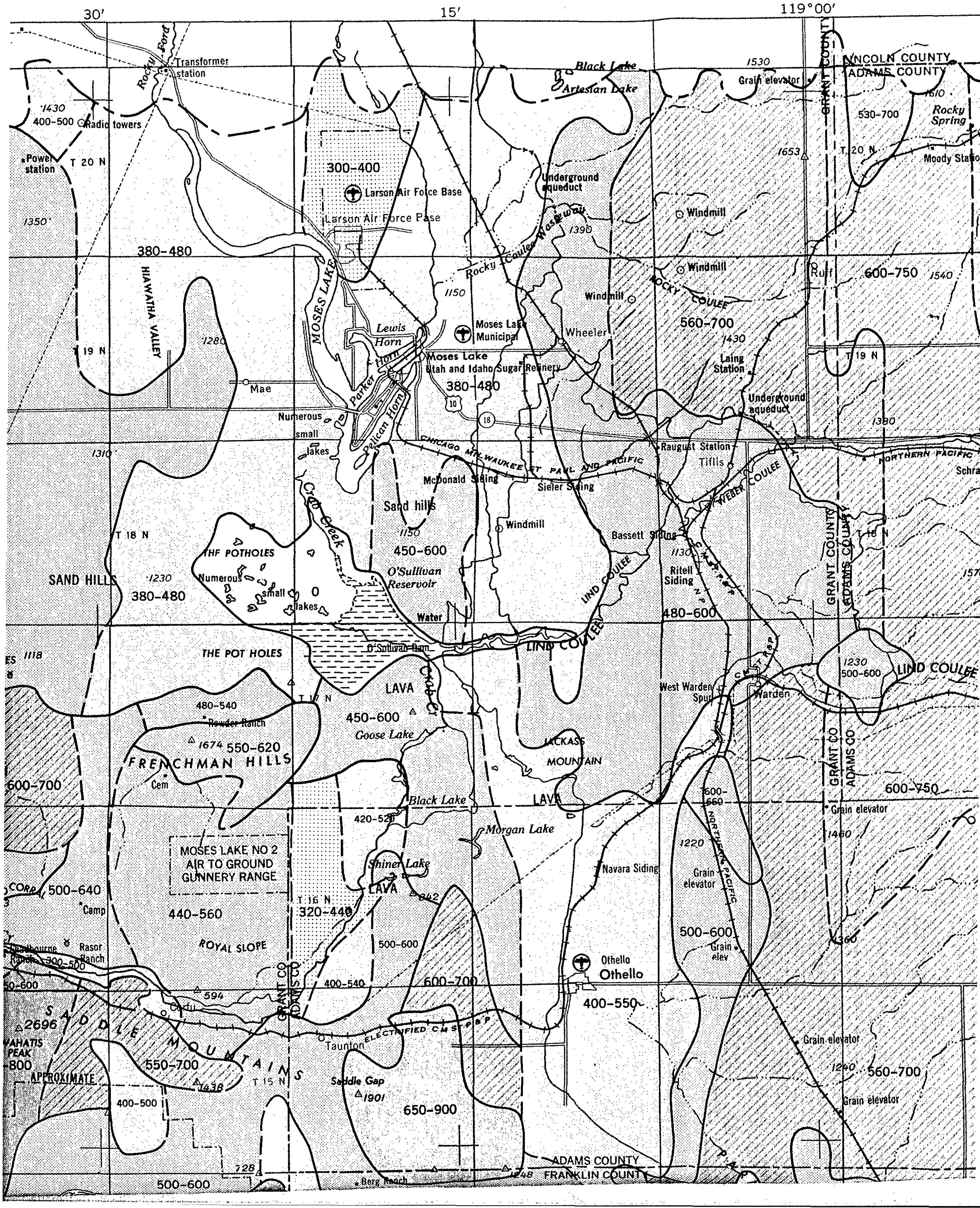
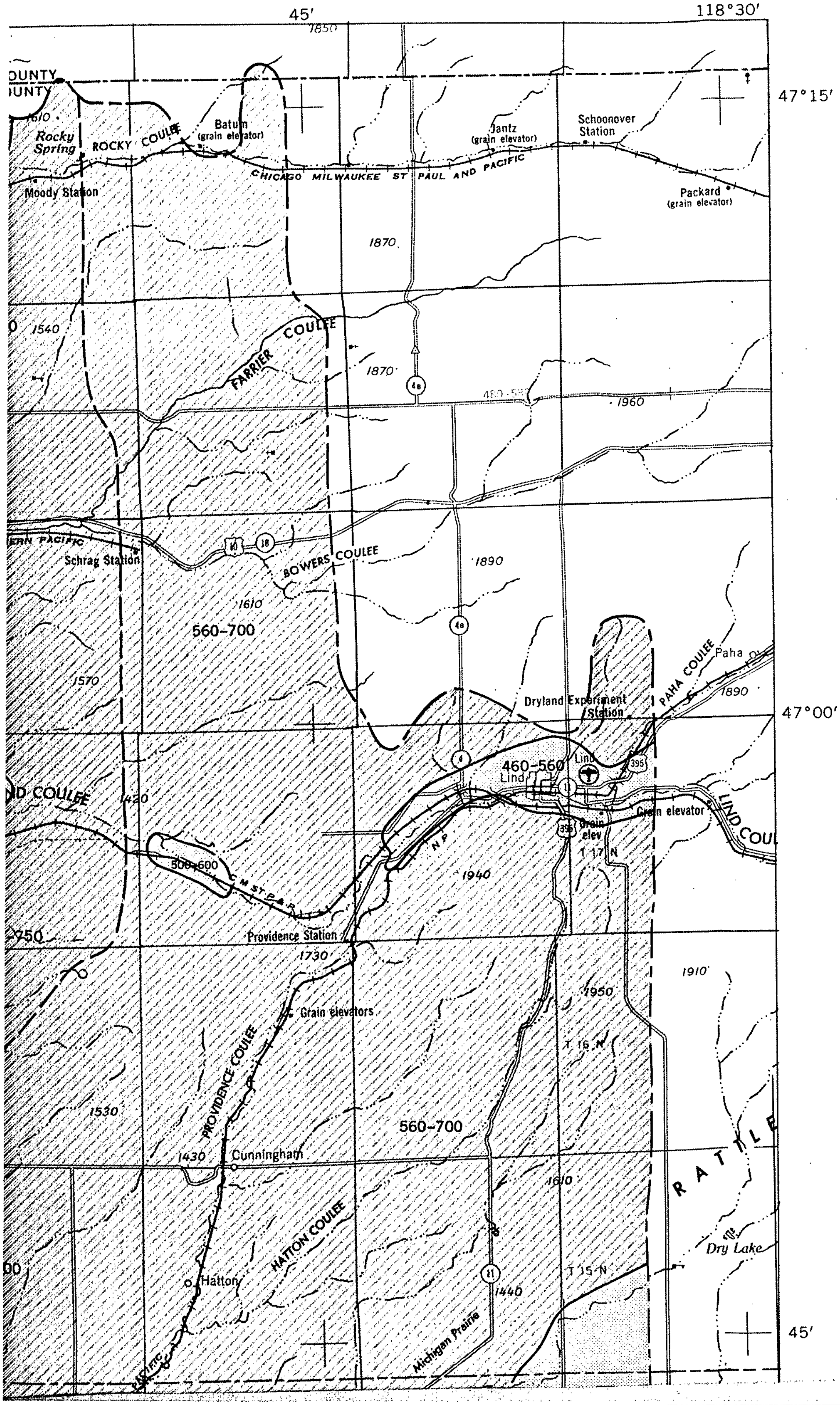


4

AEC-CEX–59.4.11
GEOPHYSICAL INVESTIGATIONS
MAP GP-307



EXPLANA

200-300

Radioactivity b

Solid where well defined, dash
Numbers indicate range of
counts per second

200-300

Single traverses made in

Hachures point toward lower

Boundary of are

More than 1000

850-1000

550-700

450-600

200-400

Generalized levels of a
in counts per

The survey
(Davis and Reinha
Parallel north-sou
were flown at a no
Single traverses w
of the aircraft was
film camera. The
from the 500-foot
ponent.

The effecti
an elevation of 50
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within the area.
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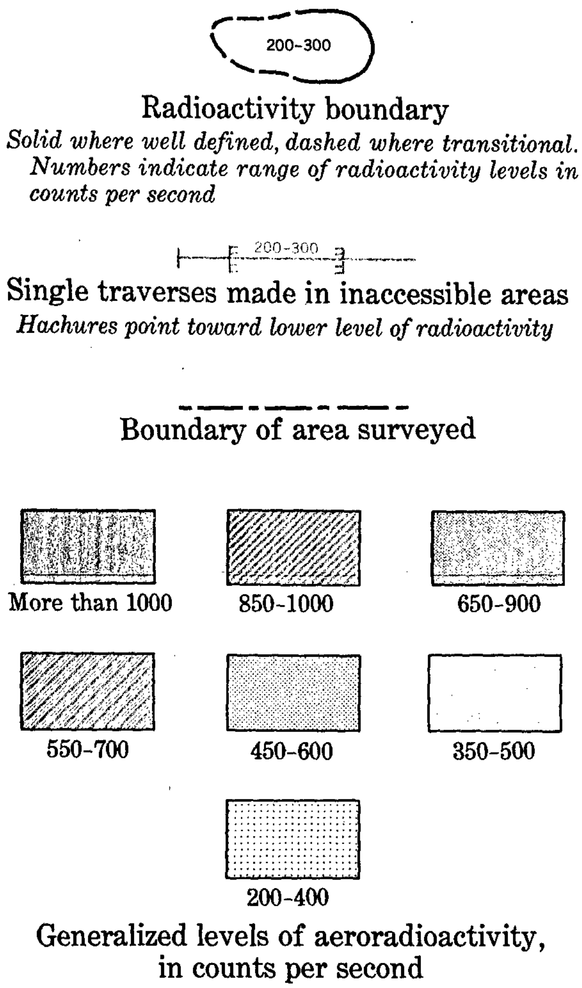
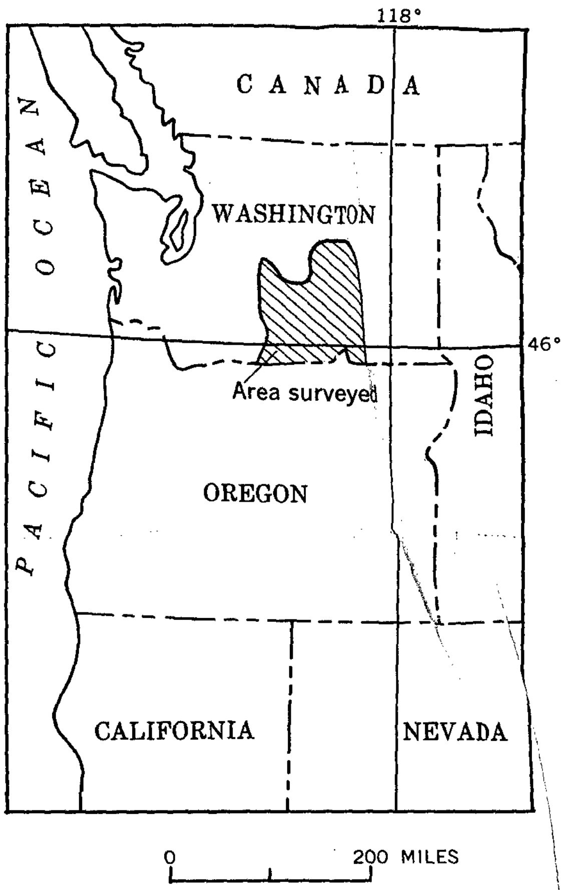
The gamma
principal sources

EXPLANATION



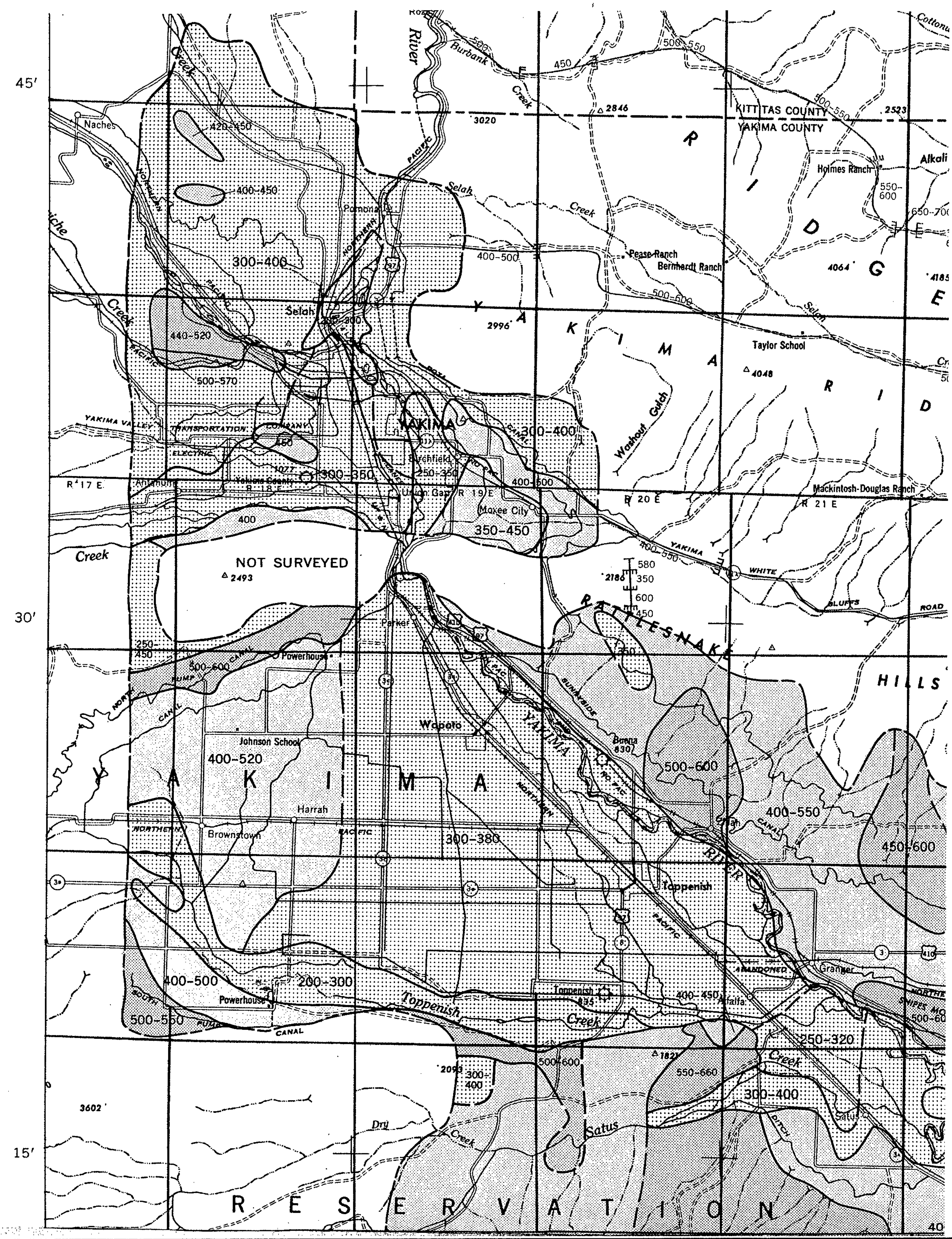


INDEX MAP

The survey was made with scintillation-detection equipment (Davis and Reinhardt, 1957[1/]) installed in a twin-engine aircraft. Parallel north-south flight traverses spaced at one-mile intervals were flown at a nominal elevation of 500 feet above the ground. Single traverses were made in inaccessible areas. The flight path of the aircraft was recorded by a gyrostabilized continuous-strip-film camera. The radioactivity data were compensated for deviations from the 500-foot surveying elevation, and for the cosmic-ray component.

The effective area of response of the scintillation equipment at an elevation of 500 feet is approximately 1,000 feet in diameter, and the radiation recorded is an average of the radiation received from within the area. The scintillation equipment accepts only pulses originating from gamma radiation with energies greater than 50 Kev (thousand electron volts). A cesium-137 source is used during periodic calibrations to assure uniformity of equipment response.

The gamma-ray flux at 500 feet above the ground has three principal sources: cosmic radiation, radionuclides in the air


45′
30′
15′
Naches
420–450
400–450
Pomona
300–400
Selah
440–520
500–570
YAKIMA VALLEY TRANSPORTATION COMPANY
ELECTRIC
YAKIMA
300–400
450
300–350
Birchfield
250–350
400–500
Union Gap
R 17 E
R 18 E
R 19 E
R 20 E
R 21 E
Moxee City
350–450
400
NOT SURVEYED
2493
Creek
Burbank
Creek
River
450
500
500
550
500–550
2846
3020
KITTITAS COUNTY
YAKIMA COUNTY
2523
Alkali
Holmes Ranch
550–600
R I D G E
Selah
Creek
400–500
Pease Ranch
Bernhardt Ranch
500–600
4064
4185
2996
Y A K I M A
Taylor School
4048
R I D
Washout Gulch
Mackintosh-Douglas Ranch
400–550
YAKIMA
WHITE
BLUFFS
ROAD
580
350
600
450
2186
RATTLESNAKE
HILLS
350
Parker
250–450
500–600
Powerhouse
Wapato
Buena
830
500–600
Johnson School
400–520
Y A K I M A
Harrah
Brownstown
NORTHERN
PACIFIC
300–380
400–550
450–600
Toppenish
Granger
400–500
200–300
Powerhouse
500–550
Toppenish
834
400–450
Alfalfa
Toppenish
Creek
250–320
2093
300–400
500–600
1821
550–660
300–400
Creek
3602
Dry
Creek
Satus
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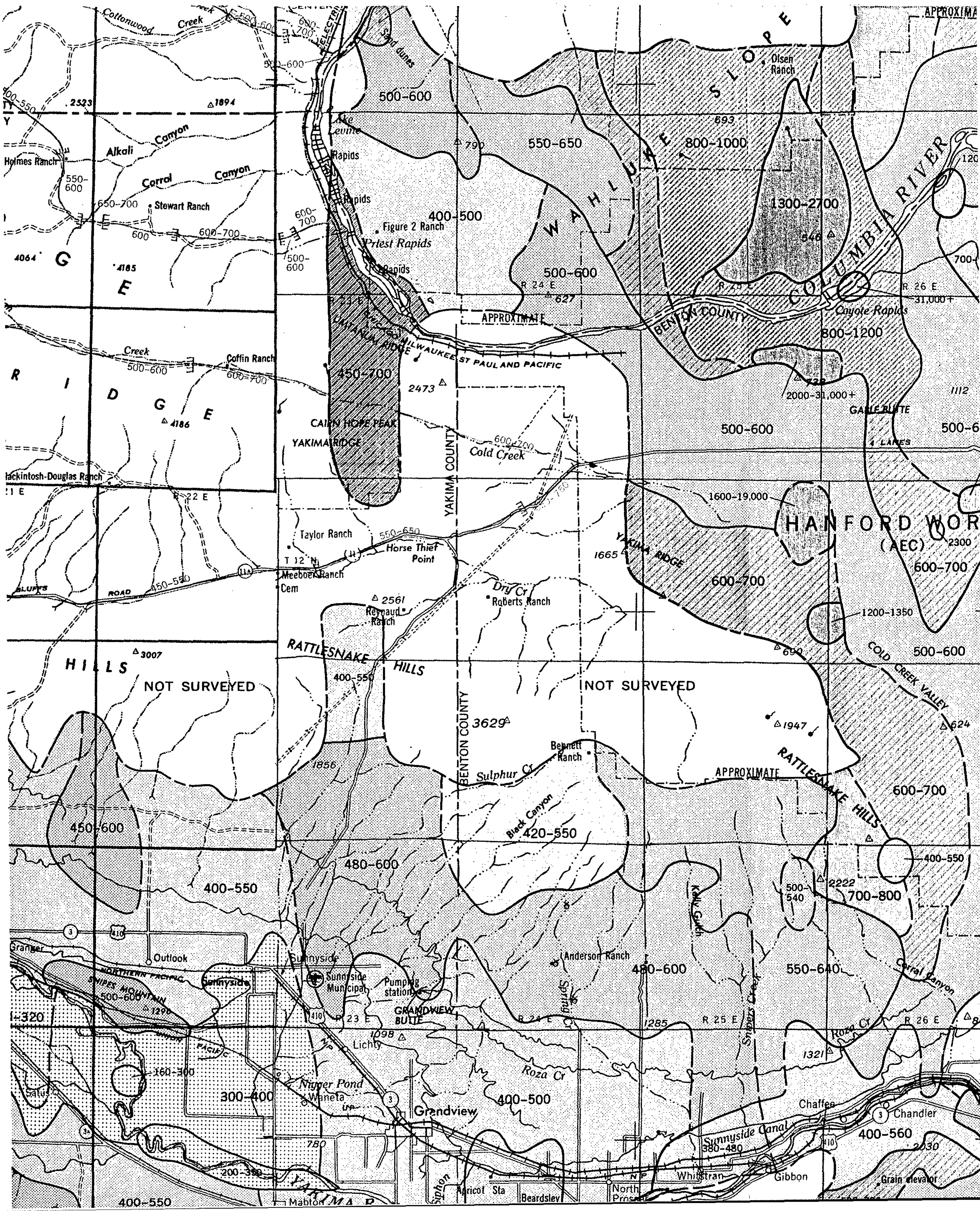
R E S E R V A T I O N

7



Cottonwood Creek
Alkali Canyon
Corral Canyon
Holmes Ranch
Stewart Ranch
Coffin Ranch
Mackintosh-Douglas Ranch
R I D G E
HILLS
NOT SURVEYED
Sand dunes
Lake Levine
Priest Rapids
Figure 2 Ranch
WAHLUKE SLOPE
Olsen Ranch
COLUMBIA RIVER
Coyote Rapids
BENTON COUNTY
YAKIMA COUNTY
APPROXIMATE
MILWAUKEE ST PAUL AND PACIFIC
UMTANUM RIDGE
CAIRN HOPE PEAK
YAKIMA RIDGE
Cold Creek
GABLE BUTTE
HANFORD WOR
(AEC)
COLD CREEK VALLEY
Taylor Ranch
Horse Thief Point
Meeboer Ranch
Roberts Ranch
Reynaud Ranch
Dry Cr
RATTLESNAKE HILLS
Bennett Ranch
Sulphur Cr
Black Canyon
Anderson Ranch
Kelly Gulch
Spring Cr
Snipes Creek
Corral Canyon
Roza Cr
Granger
Outlook
Sunnyside
Sunnyside Municipal
Pumping station
GRANDVIEW BUTTE
NORTHERN PACIFIC
SNIPES MOUNTAIN
UNION PACIFIC
Lichty
Nigger Pond
Waneta
Grandview
Satus
YAKIMA R
Mabton
Apricot Sta
Beardsley
North Prosser
Whitstran
Gibbon
Chaffee
Chandler
Sunnyside Canal
Grain elevator
Siphon
500-600
550-650
400-500
800-1000
1300-2700
800-1200
2000-31,000+
31,000+
450-700
500-600
1600-19,000
600-700
1200-1350
500-600
600-700
400-550
420-550
450-600
480-600
400-550
500-540
700-800
400-550
550-640
480-600
500-600
160-300
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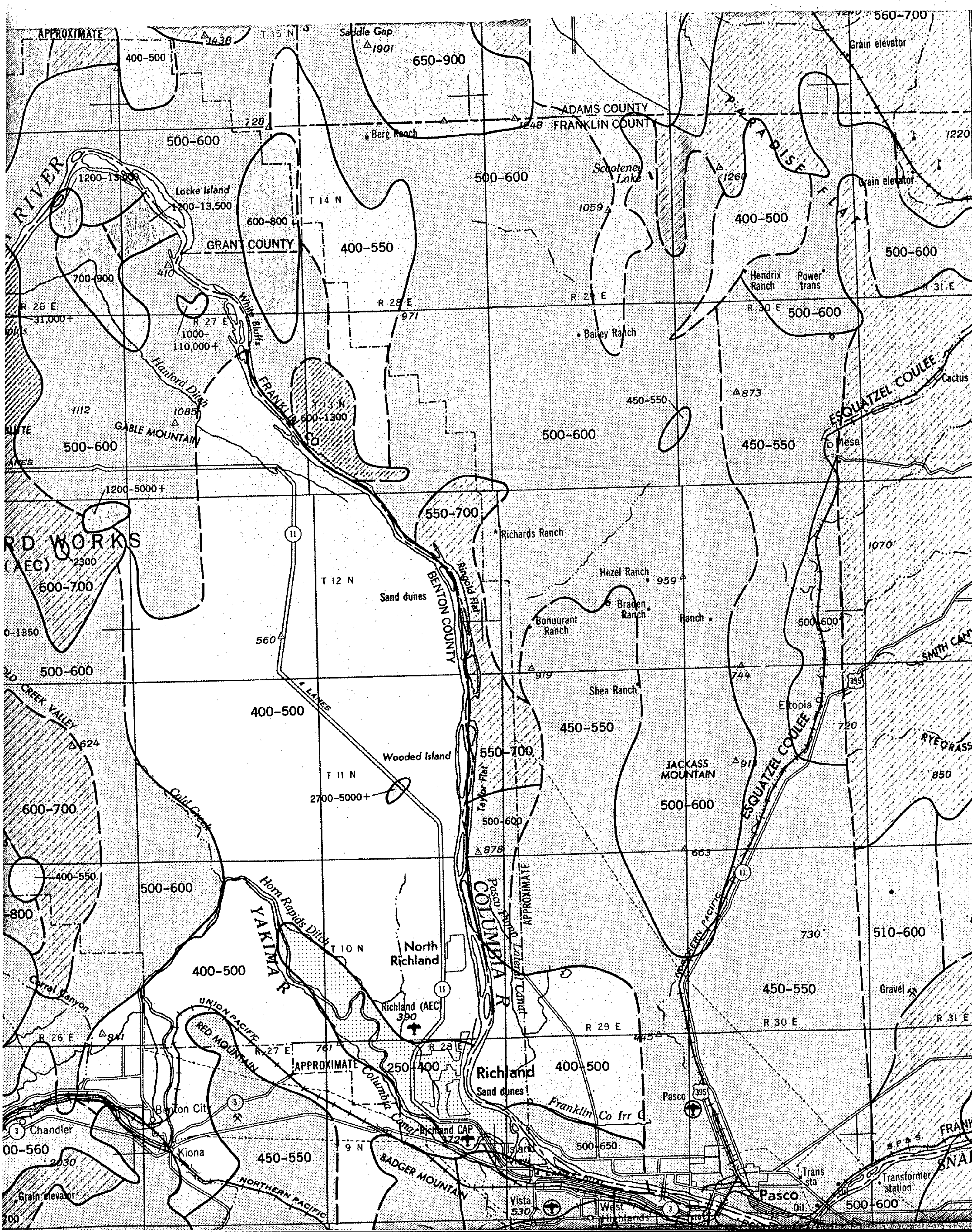
APPROXIMATE
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Saddle Gap
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650-900
560-700
Grain elevator
400-500
ADAMS COUNTY
FRANKLIN COUNTY
728
1248
Berg Ranch
500-600
1220
PARADISE FLAT
RIVER
1200-13,500
Locke Island
1200-13,500
T 14 N
Scootenet Lake
1260
Grain elevator
1059
400-500
600-800
GRANT COUNTY
400-550
500-600
410
700-900
Hendrix Ranch
Power trans
R 26 E
R 27 E
R 28 E
R 29 E
R 30 E
R 31 E
31,000+
971
500-600
1000-110,000+
White Bluffs
Bailey Ranch
Hanford Ditch
FRANKLIN CO
ESQUATZEL COULEE
Cactus
1112
1085
T 13 N
600-1300
873
450-550
GABLE MOUNTAIN
500-600
500-600
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Mesa
1200-5000+
550-700
Richards Ranch
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(AEC)
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Hezel Ranch
959
Sand dunes
Braden Ranch
Bonuurant Ranch
Ranch
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1350
560
SMITH CANYON
500-600
919
744
Shea Ranch
COLD CREEK VALLEY
Eltopia
720
400-500
450-550
624
RYEGRASS
Wooded Island
550-700
850
JACKASS MOUNTAIN
911
T 11 N
600-700
2700-5000+
ESQUATZEL COULEE
Taylor Flat
500-600
500-600
Cold Creek
878
663
400-550
500-600
Horn Rapids Ditch
COLUMBIA R
Pasco Pump Lateral Canal
APPROXIMATE
NORTHERN PACIFIC
730
510-600
800
YAKIMA R
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North Richland
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450-550
Gravel
Corral Canyon
UNION PACIFIC
Richland (AEC)
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RED MOUNTAIN
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445
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APPROXIMATE
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Richland
400-500
Sand dunes
Columbia Canal
Benton City
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BADGER MOUNTAIN
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Pasco
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500-600
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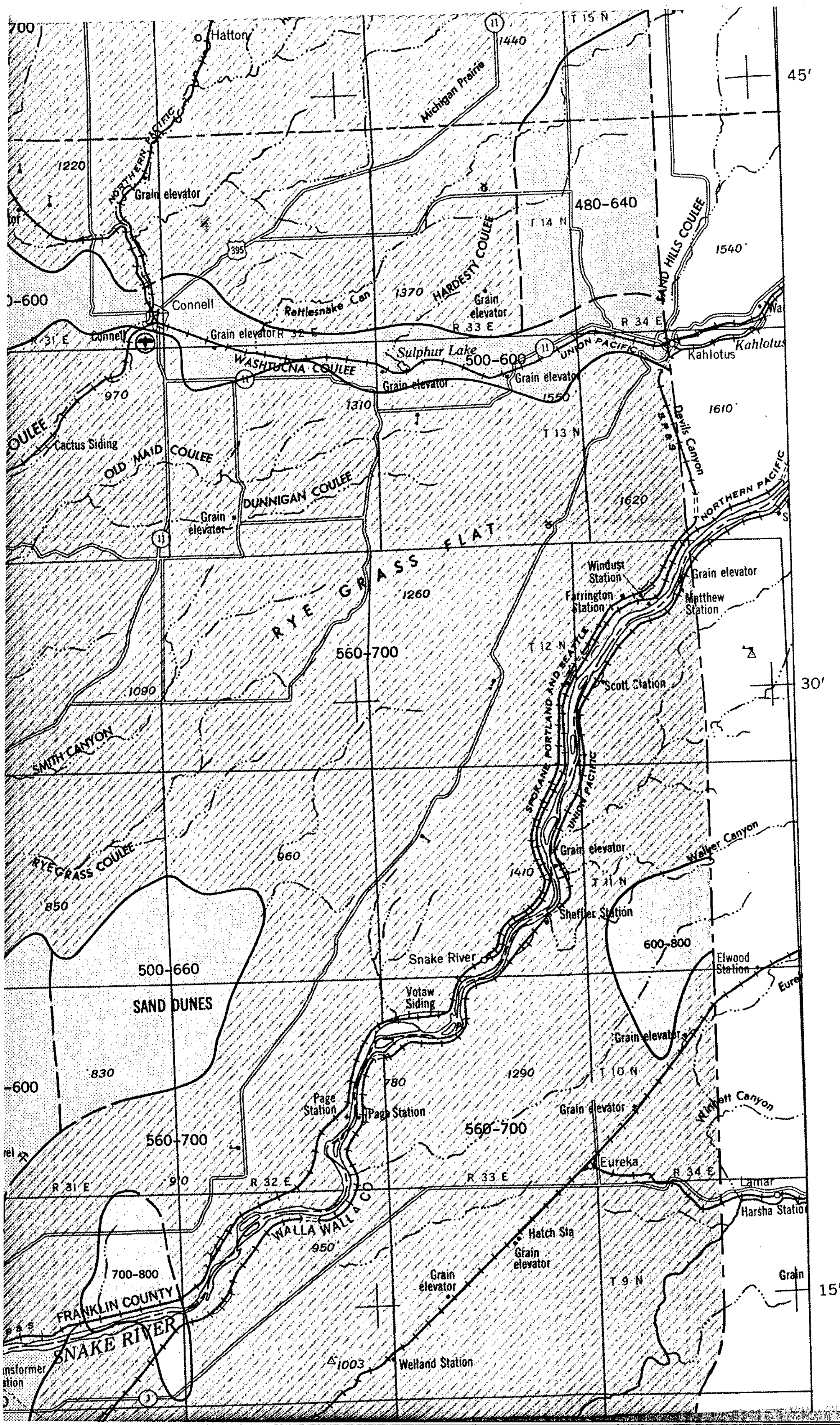

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(thousand electron volts). A cesium-137 source is used during periodic calibrations to assure uniformity of equipment response.

The gamma-ray flux at 500 feet above the ground has three principal sources: cosmic radiation, radionuclides in the air (mostly radon daughter products), and radionuclides in the surficial layer of the ground. The cosmic component is determined twice daily by calibrations at 2,000 feet above the ground, and is removed from the radiation data.

The component due to radionuclides in the air at 500 feet above the ground is difficult to evaluate. It is affected by meteorological conditions, and a tenfold change in radon concentration is not unusual under conditions of extreme temperature inversion. However, if inversion conditions are avoided, the air component may be considered to be fairly uniform on a given day in a particular area, and will not affect the discrimination of the radioactivity levels that reflect changes in the ground component.

The ground component comes from the approximate upper 6 inches of the ground. It consists of gamma rays from natural radionuclides, principally members of the uranium and thorium radioactive decay series and potassium-40, and fallout of radioactive nuclear fission products. Locally the amount of fallout, if present, must be small, as the lowest total radiation measured is 160 counts per second (cps) in areas not affected by absorption of gamma energy by water. The distribution of fallout in the area surveyed is assumed to be uniform.

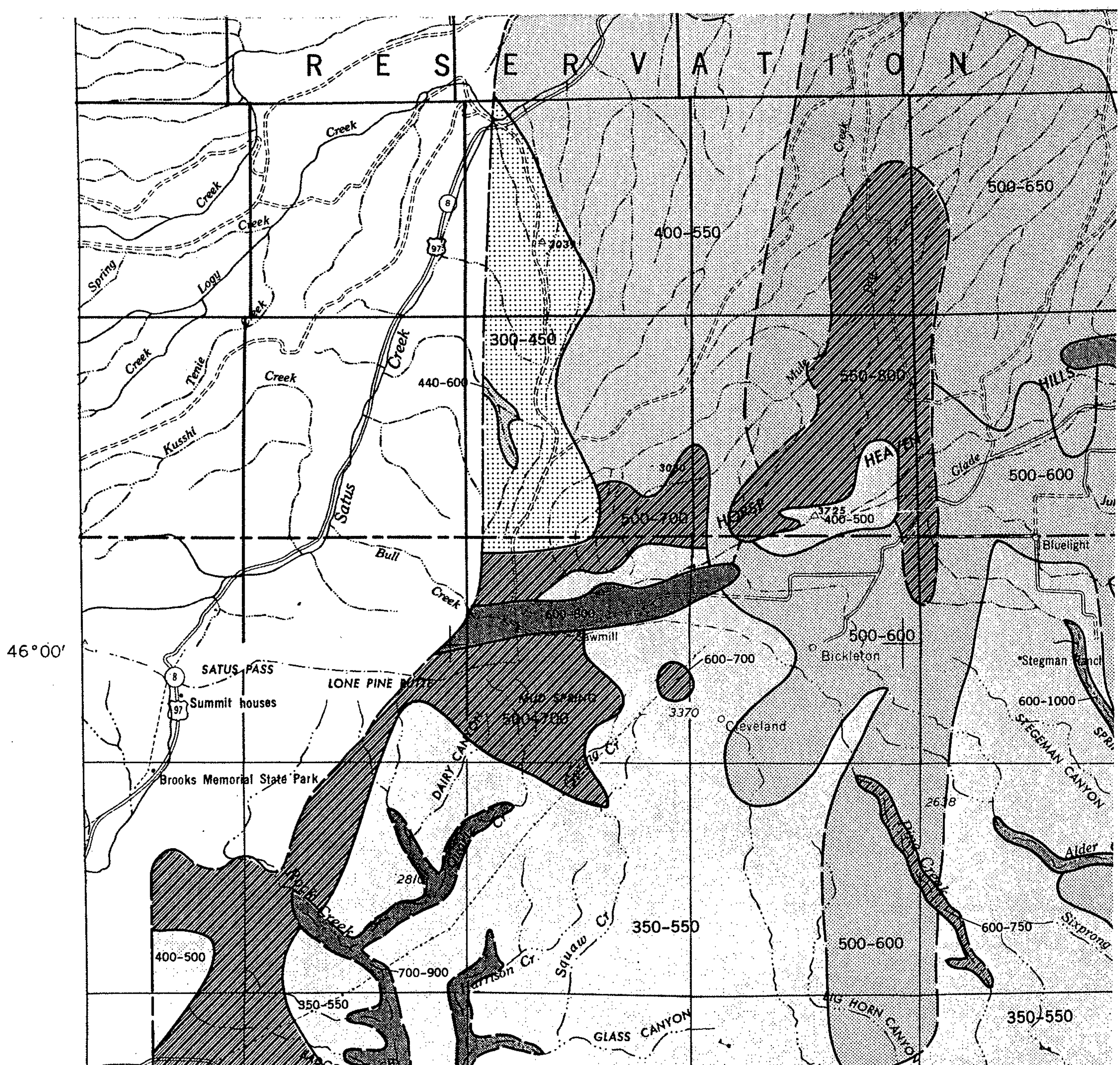
1/ Davis, F. J., and Reinhardt, P. W., 1957, Instrumentation in aircraft for radiation measurements: Nuclear Sci. and Eng., v. 2, no. 6, p. 713-727.

The natural gamma radiation measured in the Hanford Plant area has a moderate range (160 to 900 cps) and is generally related to the type of rock or soil at the surface. Bedrock is of Cretaceous to Recent age, mostly Miocene to Recent, and is extensively mantled by Pleistocene and Recent eolian deposits. Generally, lake- and stream-deposited strata are associated with low to moderate radiation (200 to 600 cps) and plateau basalt and loess with moderate radiation (400 to 800 cps). In the eastern part of the area surveyed, aeroradiation of 560 to 700 cps is generally related to loess; in the western part, along the Yakima River, aeroradiation of 200 to 400 cps is generally related to Recent alluvium.

It is believed that in this area measured radiation of more than 1,000 cps is not related to natural effects, but is due to activities within the Hanford AEC reservation.

Routine surveying disclosed anomalous aeroradioactivity of 1,000 to 2,700 cps over the Columbia River within the Hanford AEC reservation. This aeroradiation could not be due to natural effects, as only a few inches of water will completely absorb the natural radioactivity of soil and rock. Therefore, the aeroradiation appears to originate from radioisotopes in the water resulting from activities of the Hanford Plant. Normally, the altitude- and cosmic-energy compensated circuit of the Geological Survey equipment will read zero cps over large bodies of water. Quite often levels recorded over streams are from 50 to 200 cps owing to the response from land areas bordering the streams and included within the area of response.

11



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R E S E R V A T I O N
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Kusshi
Satus
Creek
Bull
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440-600
400-550
500-650
550-800
HILLS
HEAVEN
HORSE
Glade
500-600
500-700
3725
400-500
Bluelight
600-800
Sawmill
SATUS PASS
LONE PINE BUTTE
Summit houses
Brooks Memorial State Park
MUD SPRING
500-700
DAIRY CANYON
600-700
3370
Cleveland
Bickleton
500-600
Stegman Ranch
600-1000
STEGEMAN CANYON
2638
Alder
Pine Creek
Sixprong
600-750
Rock Creek
2810
350-550
Squaw Cr
Harrison Cr
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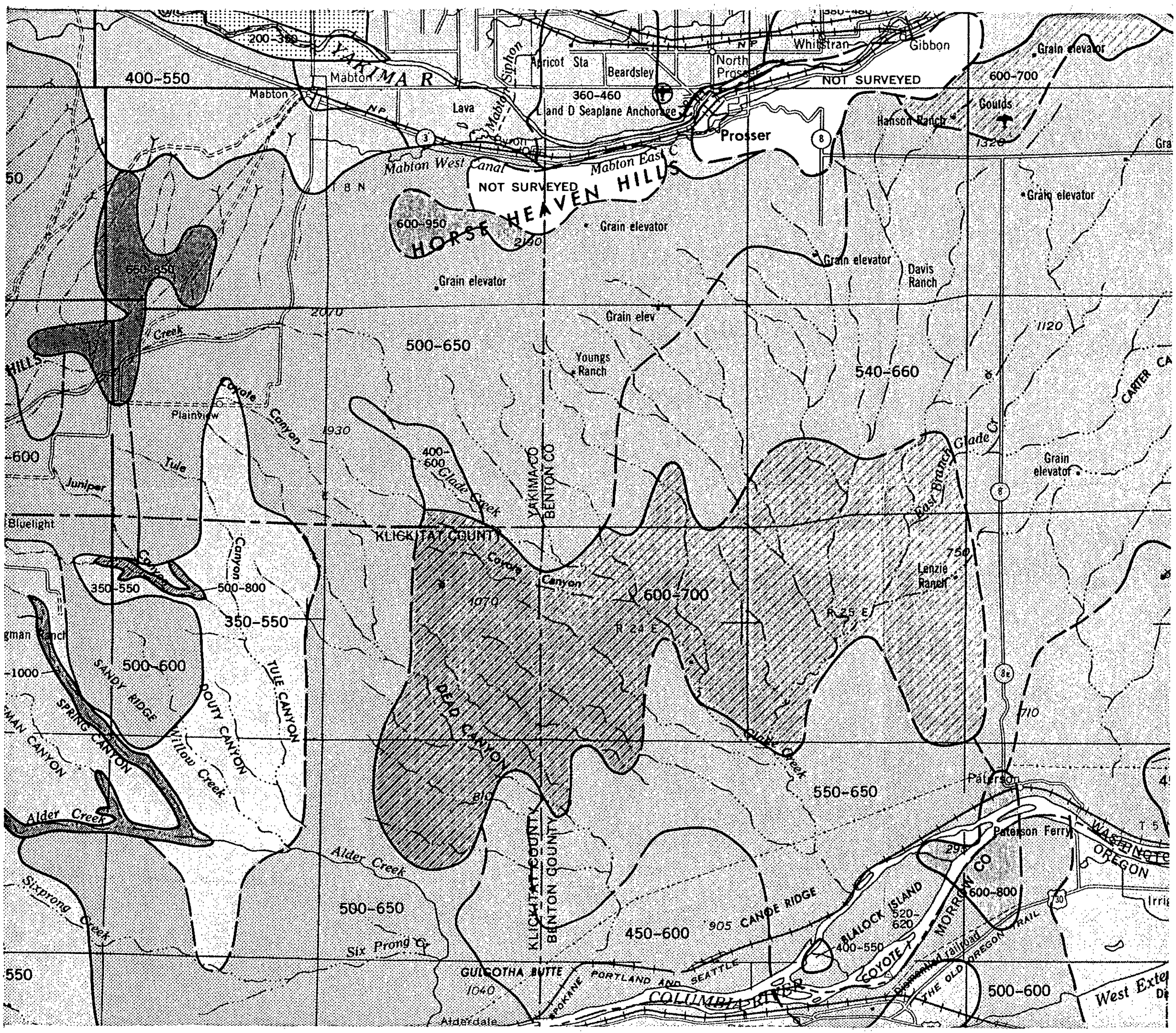
350-550
500-600
GLASS CANYON
BIG HORN CANYON
350-550
BADGER GULCH

12



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Beardsley
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Grain elevator
Goulds
Hanson Ranch
Lava
360-460
L and D Seaplane Anchorage
Prosser
Mabton West Canal
Mabton East C
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HORSE HEAVEN HILLS
600-950
Grain elevator
550-850
Davis Ranch
2070
Grain elev
500-650
Youngs Ranch
540-660
1120
CARTER CA
Plainview
Coyote Canyon
1930
400-600
Glade Creek
YAKIMA CO
BENTON CO
East Branch Glade Cr
Grain elevator
Juniper
Tule
Bluelight
KLICKITAT COUNTY
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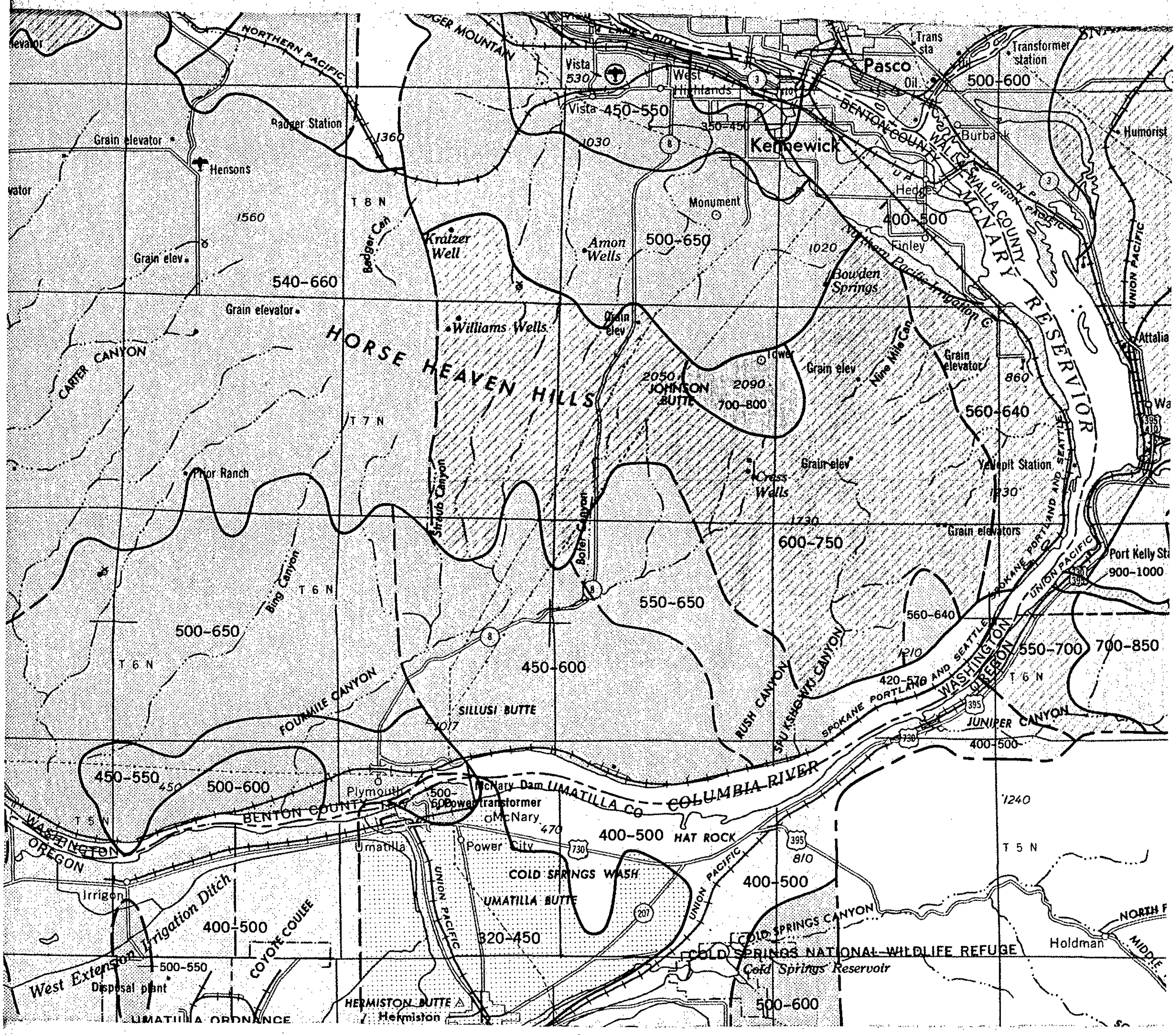
500-800
Coyote Canyon
600-700
750
Lenzie Ranch
R 24 E
R 25 E
500-600
SANDY RIDGE
DOUTY CANYON
TULE CANYON
SPRING CANYON
Willow Creek
DEAD CANYON
Glade Creek
550-650
Paterson
710
Alder Creek
Alder Creek
Sixprong Creek
500-650
KLICKITAT COUNTY
BENTON COUNTY
450-600
905
CANOE RIDGE
BLALOCK ISLAND
520-620
400-550
600-800
MORROW CO
Paterson Ferry
WASHINGTON
OREGON
Six Prong Cr
GOLGOTHA BUTTE
1040
SPOKANE PORTLAND AND SEATTLE
COLUMBIA RIVER
THE OLD OREGON TRAIL
500-600
West Exte
Alderdale
550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Kennewick
BENTON COUNTY
WALLA WALLA COUNTY
Grain elevator
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Finley
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Badger Can
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McNARY RESERVOIR
Grain elev
540-660
Bowden Springs
Northern Pacific Irrigation C
Grain elevator
Williams Wells
Grain elev
Attalia
HORSE HEAVEN HILLS
Tower
Grain elev
Nine Mile Can
Grain elevator
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CARTER CANYON
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JOHNSON BUTTE
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Prior Ranch
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Yellepit Station
Cress Wells
1230
Switzler Canyon
Bofer Canyon
1730
600-750
Grain elevators
Port Kelly St
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Bing Canyon
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560-640
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FOURMILE CANYON
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1017
RUSH CANYON
SPUKSHOWKI CANYON
420-570
SPOKANE PORTLAND AND SEATTLE
WASHINGTON
OREGON
JUNIPER CANYON
400-500
450-550
450
500-600
Plymouth
McNary Dam
UMATILLA CO
COLUMBIA RIVER
1240
T 5 N
BENTON COUNTY
Power transformer
McNary
470
400-500
HAT ROCK
WASHINGTON
OREGON
Umatilla
Power City
730
395
810
T 5 N
Irrigon
COLD SPRINGS WASH
UMATILLA BUTTE
400-500
UNION PACIFIC
West Extension Irrigation Ditch
400-500
COYOTE COULEE
320-450
COLD SPRINGS CANYON
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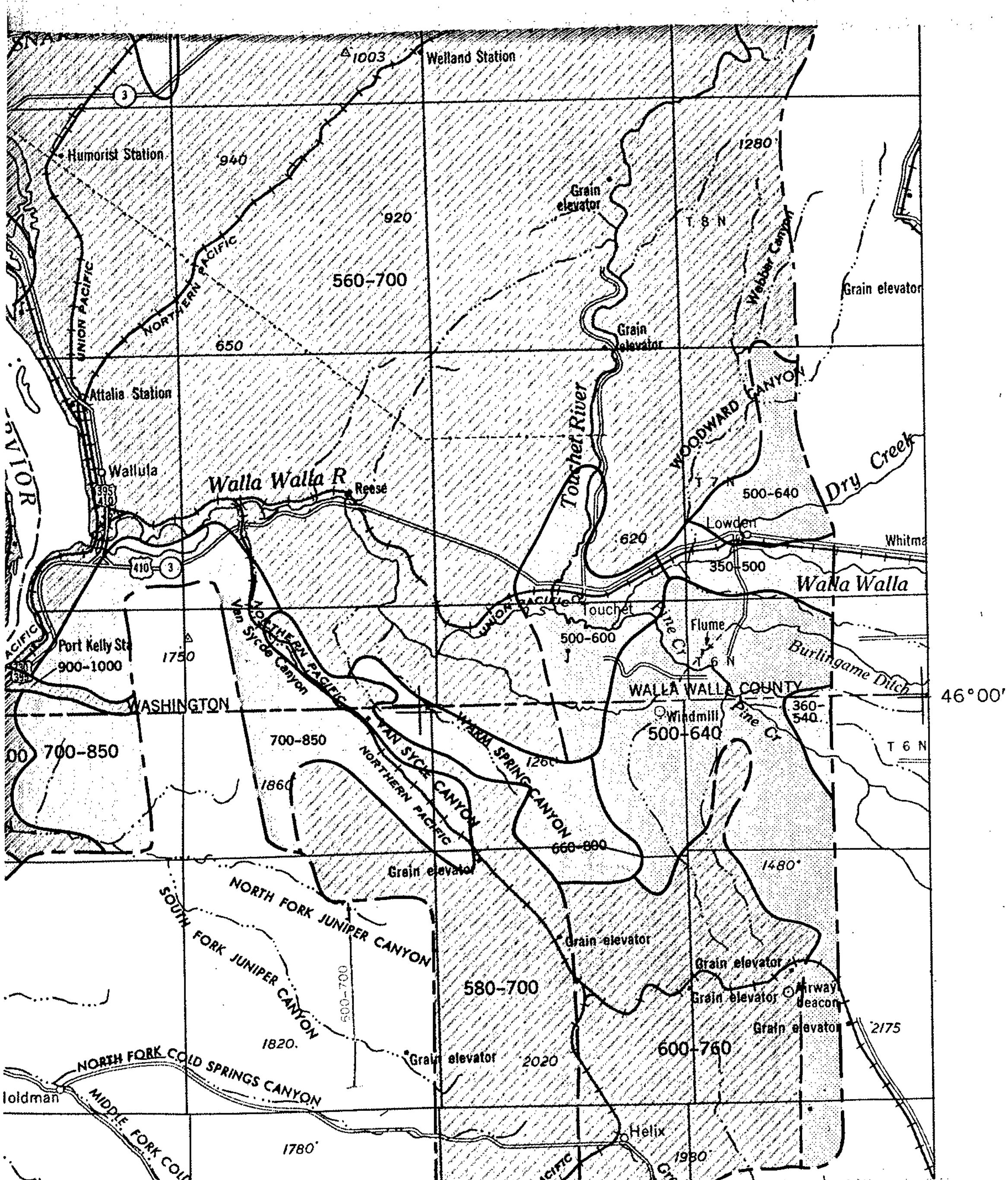

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zero cps over large bodies of water. Quite often levels recorded over streams are from 50 to 200 cps owing to the response from land areas bordering the streams and included within the area of response.

A special traverse of 110 miles was made over the river on July 8, 1959, to further check these measurements. The traverse was made at 100 feet above the river surface rather than the normal survey elevation of 500 feet, in order to nullify the ground radioactivity component of the adjoining river shores.

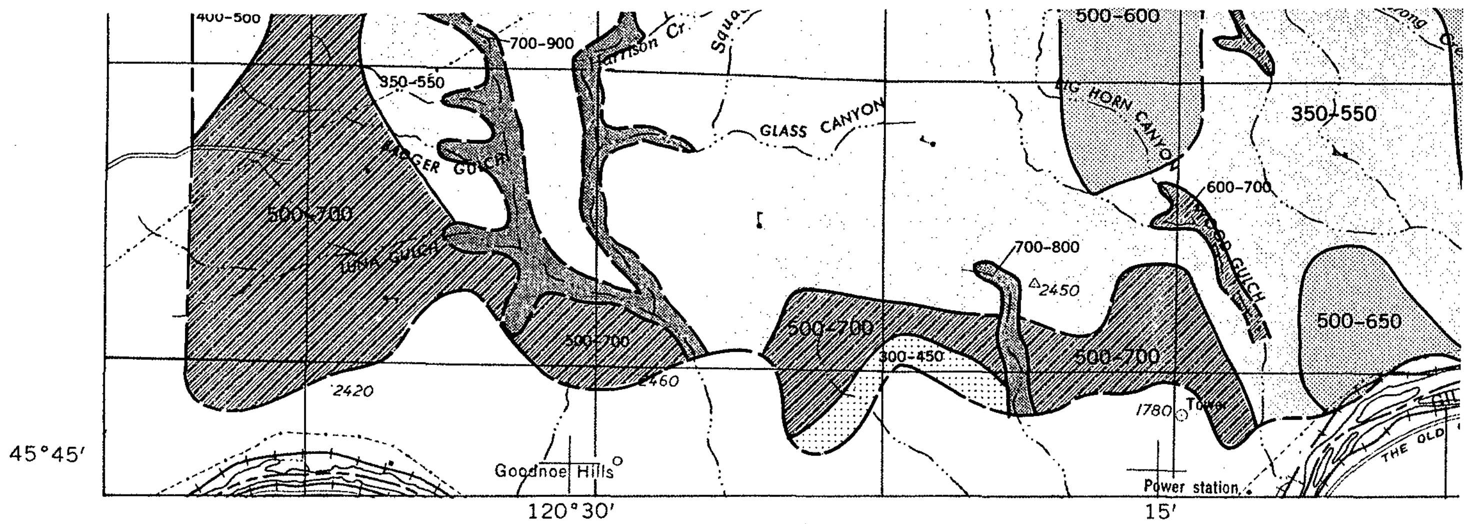
The Columbia River traverse began approximately at the western boundary of the Hanford AEC reservation and was flown downstream past Umatilla, Oreg. The aeroradiation measured during this traverse is as follows:

Radiation of 350 to 1,000 cps was first recorded about 6 miles west of Coyote Rapids. From Coyote Rapids past Locke Island and to about 4 miles southeast of White Bluffs, radiation ranged from 1,500 to 6,000 cps. Radiation from the river then steadily decreased from 1,500 cps southeast of White Bluffs to 800 cps at North Richland and to 450 cps just northwest of the Columbia-Snake River junction. At the junction, a definite interface of 350 cps was measured (Columbia, 350 cps; Snake, 0 cps), and was detectable downstream across McNary Reservoir. A 150 cps interface was then measured at the Columbia-Walla Walla River junction (Columbia, 150 cps, Walla Walla, 0 cps). From this junction to Umatilla, Oreg., radiation from the river gradually diminished until zero cps levels were measured at Umatilla. The influx of the Snake and Walla Walla Rivers undoubtedly diluted the radioactive substances in the Columbia water sufficiently to reach the normal zero cps level. Analyses of the Columbia water indicate that " .... the concentrations of these radioisotopes are well below the maximum permissible concentrations recommended for the protection of the general public"1/.

Detailed information on the aeroradioactivity survey of the Hanford Plant area is contained in another report2/.

1/Rostenbach, Royal E., 1959, Radioactivity levels and temperature variations of the Columbia River: Nuclear Engineering, Part V, Chemical Engineering Progress Symposium Series, vol. 55, no. 22, p. 37-43.

2/Schmidt, R. G., 1961 Aeroradioactivity survey and areal



Base from Army Map Service, Corps of Engineers,
1:250 000-scale topographic maps, Pendleton,
Ritzville, The Dalles, Walla Walla,
Wenatchee, Yakima sheets

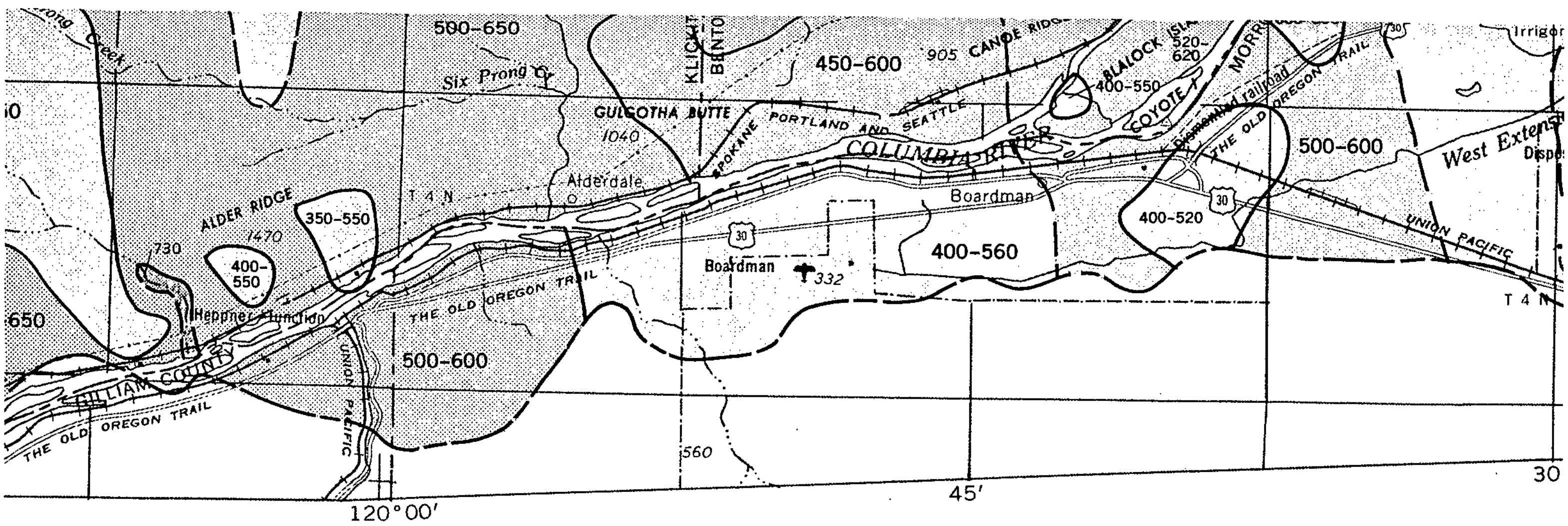
TRUE NORTH

MAGNETIC NORTH DEVIATES
FROM 20°30′E TO 22°30′E
WITHIN MAP AREA

AERORAI

AEC-CEX—59.4.11
GEOPHYSICAL INVESTIGATIONS
MAP GP-307

17



RADIOACTIVITY OF THE HANFORD PLANT

By
Robert G. Schmidt

SCALE 1:250 000

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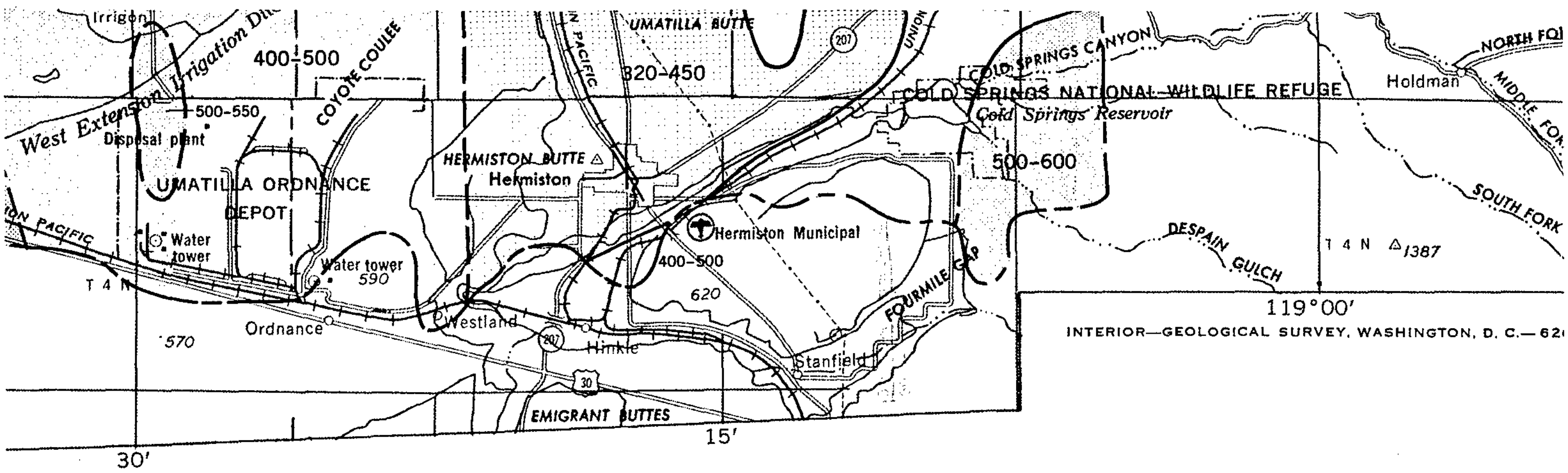
1961



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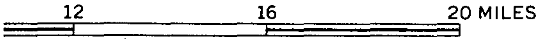

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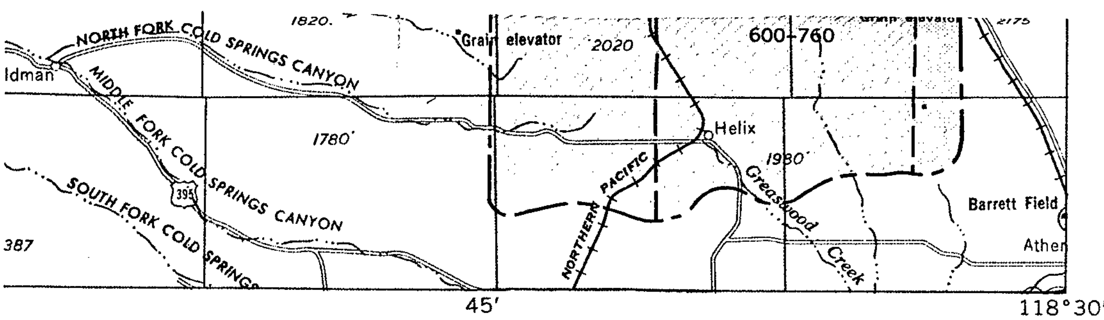

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Aeroradioactivity survey made at 500 feet above the ground under the direction of J. L. Meuschke and P. W. Philbin, 1959

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temperature vari
Part V, Chemica
no. 22, p. 37-43.
2/Schmidt
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A.E.C. Report C
Services, Depart

For sale by U. S. Geological Survey, price 50 cents
Washington 25, D. C.

1/Rostenbach, Royal E., 1959, Radioactivity levels and temperature variations of the Columbia River: Nuclear Engineering, Part V, Chemical Engineering Progress Symposium Series, vol. 55, no. 22, p. 37-43.

2/Schmidt, R. G., 1961 Aeroradioactivity survey and areal geology of the Hanford Plant area, Washington and Oregon, U. S. A.E.C. Report CEX-59.4.11, available from Office of Technical Services, Department of Commerce, Washington 25, D. C.